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Mountain Goat Habitat Supply Modeling in the Mackenzie Timber Supply Area, North-Central British Columbia

Version 1.0 – December 2003

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THE OSPIKA MOUNTAIN GOAT PROJECT

Adaptive Management & Habitat Supply Modeling

The Ospika Mountain Goat Project (OMGP) is a multi-phase, collaborative study focused on the development and implementation of effective policy to support integrated management of forest harvesting and mountain goat habitat in the Mackenzie Timber Supply Area, north-central British Columbia. The OMGP was initiated in 2001 by the Peace/Williston Fish and Wildlife Compensation Program and Slocan Forest Products Ltd - Mackenzie Operations. Collaborators from private industry and government ministries are active in the project through participation in the regional, multi-agency Mountain Goat Management Team.

Project components include an active Adaptive Management Trial in the lower Ospika River valley, Resource Inventory throughout the Mackenzie TSA, Habitat Supply Modeling, and Policy Development.

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British Columbia

AUTHOR'S NOTE

This document summarizes the complete proceedings and results of preliminary Mountain Goat Habitat Supply Modeling (HSM) activities conducted between January and March 2003 to fulfill the objectives of Slocan Forest Products Ltd. - Forestry Innovation Investment contract #FII-02-01 R2003-0208.

A draft of this document was submitted to FII in March 2003 as:
Hengeveld, P.E., M. Wood, R. Ellis, R. Lennox. 2003. Mountain goat habitat supply modeling, with preliminary application in the Ospika River drainage, north-central B.C. Version 1 Draft. Wildlife Infometrics Inc Report No. 46. 44 pp. plus appendices.

This document (Version 1.0 – December 2003) has been edited to improve clarity in presentation of the models. The material presented herein will be further referenced, tested, refined, peer-reviewed, and updated as Goat HSM is developed in 2003-2004.

ABSTRACT

Slocan Forest Products Ltd., Mackenzie Operations, (Slocan) secured Forestry Innovation Investment (FII) funds to initiate development of a Habitat Supply Model (HSM) for mountain goats (*Oreamnos americanus*) between January and March 2003. The intent was to construct a preliminary, Netica©-based habitat supply model to address management concerns for mountain goat populations potentially impacted by forest harvesting (particularly, where goats use low-elevation mineral licks in areas with high timber supply value).

Initial Goat HSM development was accomplished through a multi-agency, collaborative effort during a series of three workshops held in February and March 2003. Workshop discussions resulted in the development of 4 mountain goat habitat models, and 4 sub-models that describe mountain goat management factors:

- Low Elevation Mineral Licks
- Trails to Low Elevation Mineral Licks
- Summer Escape Habitat
- Winter Escape habitat

- Ground disturbance
- Aerial disturbance
- Hunting of goats
- Predation of goats

A trial application of the Goat HSM developed during the workshops was conducted using data from the lower Ospika River drainage. Project results were presented to stakeholders and the potential for: (1) further development and application of Goat HSM; (2) criteria for model interpretations and evaluations; and (3) approaches to model testing, were discussed.

Goat HSM development and application is expected to continue beyond March 2003. The long-term goal is to develop a Goat HSM that is a useful operational decision-support tool at the Forest Stewardship Plan level, and that will contribute to developing adaptive management strategies that can be applied to other geographical areas (regionally and provincially). Ultimately, the aim is to provide a tool that can be used by the forest industry at a regional and provincial level to plan the provision of mountain goat habitat in the context of sustainable forest management.

This document presents the FII deliverables resulting from project activities completed in February and March 2003, and identifies a framework for further development of Goat HSM:

1. A discussion of current and future development and application of Goat HSM;
2. An agenda and post-workshop summary for each modeling workshop (Appendix A);
3. A demonstration of the trial application (Appendices B and C);
4. Annotated, Netica©-based, mountain goat habitat supply models (4 habitat models, and 4 management factors sub-models; included on enclosed disk).

ACKNOWLEDGMENTS

This project was proposed by Dr. Scott McNay, Forest Biologist, Slocan Forest Products, and achieved by a co-operative, multi-agency working group.

Funding was provided by the Forestry Innovation Investment Forest Research Program.

The following participants were key contributors in determining mountain goat ecological relationships and developing the mountain goat habitat supply models:

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Robert McCann (Wildlife Ecologist, Wildlife Infometrics Inc) and Andrea Doucette (GIS Specialist, Wildlife Infometrics Inc) provided technical advice on running the habitat supply models.

Doug Heard (Wildlife Specialist, MWLAP), Dr. Scott McNay (Forest Biologist, Slocan Forest Products Ltd.) and Glen Keddie (Wildlife Ecologist, Wildlife Infometrics Inc) provided comments on draft versions of this document.

Our modeling approach and documentation are based on principles and techniques developed by the CHASE model:
McNay, S., K. Zimmerman, and R. Ellis. 2003. Caribou habitat assessment and supply estimator (CHASE): Using modeling and adaptive management to assist implementation of the Mackenzie LRMP in strategic and operational forestry planning. Wildlife Infometrics Report No. 55. Wildlife Infometrics Inc., Mackenzie, British Columbia. 101pp. plus appendices.

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1.0 INTRODUCTION

1.1 Mountain goat ecology in the Mackenzie TSA

Mountain goats (*Oreamnos americanus*) are habitat specialists. Although they are found primarily in rugged terrain at high-elevations, some populations show significant dependence on and fidelity to lower elevation habitats. Mountain goats use forested areas to access low-elevation mineral licks from early spring to late fall (Hebert 1967), and for forage and cover during the winter. Mineral licks and their access trails are traditionally used by successive generations of goats (Fox and Smith 1988).

Relative to other ungulates, little is known about mountain goat ecology, and few data exist on mountain goat numbers and meta-populations in the Mackenzie Timber Supply Area (TSA). Some data on goat population distributions has been obtained through aerial ungulate inventories conducted throughout the TSA, including the west side of the lower Ospika R (Hatler 1988), the Russel Range (Watts and Child 1986, Corbould 2001), the Akie River (Wood 1994), and the Nabesche River (Wood 2002). A random sample mountain goat census conducted in the Ospika R drainage in November 2002 provided a sightability-corrected population estimate of 345 animals (90% confidence limits of 140 to 595 animals; Hengeveld 2003).

In 1999 and 2000, the Peace/Williston Fish and Wildlife Compensation Program identified and investigated mineral licks in several of the Mackenzie TSA's major river valleys to assess their use by mountain goats (PWFWCP, unpublished data). Five large, valley bottom clay bank mineral lick complexes were located in the lower Ospika. Four of these (referred to as Lick 17, Lick Complex 28, Lick Complex 34, and Lick 40) were identified as being well used by goats, as determined by the abundance of animal sign (e.g., fecal pellets, hair) and the presence of well-worn forest access trails. Notable goat mineral licks were also identified at Thane Cr (upper Osilinka R), and along Lay Cr (upper Mesilinka R).

The four active goat mineral licks in the lower Ospika R valley are identified as study sites in an active adaptive management trial currently in progress. The trial is a component of the Ospika Mountain Goat Project, and is focused on evaluating the effects of two forest harvesting scenarios on mountain goat use of low-elevation mineral licks (Wood and Hengeveld 2003).

1.2 Mountain goat management concerns in the Mackenzie TSA

Mountain goat fidelity to local sites like mineral licks renders goats particularly sensitive to disturbance from, and displacement by, various industrial activities (Hebert and McTaggart-Cowan 1971, Chadwick 1983, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Forest development has the potential to reduce or eliminate access to mineral licks, cause disturbance to goats on their winter range, and create access for hunters to previously un-hunted and vulnerable goat populations.

With the continued demand for wood supply, forest development is expanding throughout the Mackenzie TSA, into additional tributary watersheds and higher-elevation forests. In recent years, management concerns regarding mountain goats have been raised, as forest harvesting has begun

to encroach on low elevation mountain goat habitat (e.g., in the lower Ospika R, Akie R, and Pesika Cr drainages, Thane Cr; Lay Cr).

The BC Identified Wildlife Management Strategy (B.C. MWLAP in prep.), recently incorporated into the Forest Practices Code (FPC), and the Mackenzie Land and Resource Management Plan (LRMP; B.C. MSRM 2000) identify the mountain goat as a regionally important species of special management interest. While the LRMP identifies the need to appropriately manage mountain goats and their habitats, it defers all management to policies defined at a regional level. Currently, no firm management policies have been developed. The FPC provides some management direction in the form of General Wildlife Measures, Ungulate Winter Range, and Identified Wildlife Management Strategy recommendations, however, the recommendations are generalized, static, and limited in scope. There is a recognized need by the forest industry and goat management biologists for developing mountain goat management guidelines that consider the full range of habitat types used by mountain goats, incorporate some evaluation of industrial disturbance and cumulative effects over time, and facilitate operational planning for the sustainability of forest values. The Ospika Mountain Goat Project aims to address this need.

1.3 The Ospika Mountain Goat Project

The Ospika Mountain Goat Project (OMGP) is a multi-phase, collaborative study focused on the development and implementation of effective policy to support integrated management of forest harvesting and mountain goat habitat in the Mackenzie TSA (Wood and Hengeveld 2003). The OMGP was initiated in 2001 by the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) and Slocan Forest Products Ltd. – Mackenzie Operations (Slocan). Collaborators from private industry and government ministries are active in the project through participation in the regional, multi-agency Mountain Goat Management Team (MGMT).

Project components include an active Adaptive Management Trial in the lower Ospika R valley, Resource Inventory throughout the Mackenzie TSA, Habitat Supply Modeling, and Policy Development.

Overall, project results are expected to:

- improve current knowledge of mountain goats in the Mackenzie TSA,
- provide a baseline for Sustainable Forest Management (SFM) monitoring programs where mountain goats are identified as an indicator of forest resource sustainability,
- facilitate improvements (e.g., time- and cost-efficiencies) in operational planning at the Forest Stewardship Plan level, and
- support forest industry certification efforts.

1.4 Habitat Supply Modeling

Models may be defined as conceptual representations of a system. Habitat supply models can be presented graphically to illustrate the context of the models and relationships among model components (Jones *et al.* 2002).

In general, habitat supply models depend on expressions of "habitat relationships" which are typically formed on the basis of "resource inventory" projects (Jones *et al.* 2002). Provided there are forecasts of "predicted forest and stand conditions" available, these can then be translated into "predicted habitat supply". "Population response" to habitat supply can then be modeled or inferred from the supply of habitat and "interpretations" made.

Habitat supply models are enhanced if the predicted future conditions of the forest come from a "disturbance scheduler" or forest estate model (Jones *et al.* 2002) because the estimates of habitat supply and timber supply can then be interpreted together to enable decisions about "trade-offs". The desire to understand, or ask questions, about such trade-offs usually comes from attempting to introduce or implement a "policy or management alternative" (i.e., to consider the implications of doing so). The policy information can be used as input to the disturbance simulator in scenario runs to form the basis for use of habitat supply model. Finally, a useful and often-requested comparison in habitat supply analyses is a "natural disturbance" base case that can be simply input to the disturbance simulator and used in the habitat supply model to make predictions about habitat supply.

1.5 Goat Habitat Supply Modeling Objectives

Slocan secured Forestry Innovation Investment (FII) funds for the period of January through March 2003 to initiate Habitat Supply Modeling (HSM) for mountain goats in the Mackenzie TSA. The intent was to construct a preliminary habitat supply model to address management concerns for mountain goat populations potentially impacted by forest harvesting (particularly, where goats use low-elevation mineral licks in areas with high timber supply value).

This was identified as the initial step in developing a comprehensive habitat supply model that will ultimately link mountain goat and habitat monitoring information, forest development planning, and forest management activities. Model development and application is expected to continue beyond March 2003 through a large-scale, collaborative, and comprehensive modeling effort similar in scope to the Omineca Northern Caribou Project (see http://www.slocan.com/irm/projects/caribou/model/index.html). The long-term goal is to develop a Goat HSM that is a useful operational decision-support tool at the Forest Stewardship Plan level, and that will contribute to developing adaptive management strategies that can be applied to other geographical areas (regionally and provincially). Ultimately, the aim is to provide a tool that can be used by the forest industry at a regional and provincial level to plan the provision of mountain goat habitat in the context of sustainable forest management.

Overall, the Goat HSM project has the following objectives:

1. Develop a common understanding of goat management and forest management among researchers and managers, to aid in ongoing policy development and sustainable management of mountain goats.
2. Develop decision-support tools to be incorporated into operational planning (forest stewardship plans) and policy development.
3. Develop analytical approaches that will incorporate and utilize fieldwork results in an effective manner.
4. Develop models that incorporate the spatial components of habitat selection that will allow informed and testable predictions of mountain goat responses to managed and natural changes (i.e., disturbances).

5. Use the model(s) to promote learning and the implementation of alternative operational management programs.

1.6 Model Application to Land Use Planning

1.6.1 Operational Planning (Forest Development / Forest Stewardship Plans)

Goat HSM assists foresters and engineers faced with numerous challenges, such as: (1) locating roads and cut-blocks in a design that meets management objectives for goats; (2) providing the mills with the volume, species and size of timber they desire; (3) managing costs of development and logging through equipment choice, seasonal timing, amount of road constructed; silvicultural treatment options; and other factors, by providing a mechanism to:

1. Identify goat habitat. This would facilitate pro-active management by improving forest planner awareness of habitat potential prior to the commencement of development planning activities. If goat habitat was confirmed in the field, cutblock and access road configurations would consider key habitat features at the "proposed" stage (i.e. the presence of goat habitat would be made known to government during consideration for approval). It would reduce situations of reactive management, where government and industry work to reach agreement on appropriate management under more onerous time pressures (harvest schedule), and typically after significant operational investments have already been made (layout activities, cutting permit approval, etc.).

2. Compare 5-year operational plans with alternative development options. This information would be used by industry to demonstrate that proposed blocks and roads "adequately manage and conserve" forest resources (section 41.1(b) of the Forest Practices Code), as they pertain to mountain goats and their habitat. The sequence could be: (1) prepare a development plan for an area; (2) prepare road and cutblock data information corresponding to the plan; (3) run the modeling tool to predict results; (4) evaluate the predicted results (indicators) against targets, and compare predicted results with available field monitoring data; (5) review and revise the development plan; and (6) repeat the cycle.

3. Guide road and cutblock placement, and to evaluate the location and season of use of roads and cutblocks with respect to their effect on the various types of goat habitat modeled.

4. Evaluate the cumulative effects of current year activities in combination with past activities and/or future (5 year) plans.

5. Assess the following management activities as management "levers" in developing or modifying plans:

    - Avoid or buffer goat habitats (escape terrain, lick, trail).
    - Manage the season of activity (summer or winter) around goat habitats (escape terrain, lick, trail). This would include aerial and ground activity – reconnaissance, layout, road building, road traffic, logging and hauling.
    - Establish barriers to access (e.g. road rehabilitation).
    - Manage human access.

- Manage the timing / intensity of ground activities in an area.
- Manage the timing / intensity of aerial activities in an area.
- Implement alternative goat hunting regulations and / or closures to compliment habitat management.
- Implement WHA or Resource Feature designation for an area, where appropriate.

6. Try alternatives ("gaming") with the model(s) to explore the implications that alternative forest management activities have on goat habitat and operational considerations.

7. Design adaptive management experiments to test alternative stand management activities and their implication to goat habitat value (e.g., the Ospika Goat Adaptive Management Trial; Wood and Hengeveld 2003).

8. Demonstrate that forest licensees are upholding the intent of the Mackenzie LRMP.

The model can test alternative management scenarios of interest to managers and planners. In order to have the model behave as realistically as possible, the starting point for all scenarios might be the current landscape situation (e.g., roads and cut-blocks). For simplicity, the planned roads and cut-blocks are assessed, and results determined for each year over the life of the plan of interest (normally 5 years).

Over time, it is anticipated that targets and/or limits regarding the amount of "impact" that is considered acceptable regarding each type of goat habitat will be developed. These targets will be based on the determination of what is "significant" impact to the various types of goat habitat. The model will assist in promoting this discussion and focusing efforts to acquire additional field information. Once developed, these targets or limits could be used to guide decisions regarding when change is required in an operational plan, however in the interim the model(s) provides a mechanism for prediction of site-specific impacts on goat habitats.

1.6.2 Tactical and Strategic Planning

Goat HSM can evaluate local habitat quality for mountain goats, and assess how habitat value might change over time under alternative management scenarios. Tactical planning might require making habitat value comparisons within geographic areas that support mountain goats, to assess the implications of management in one part of a range compared to another (e.g., one or more landscape units). Comparisons can also be made between goat population areas, to support informed decision-making and planning at the strategic level (e.g., Mackenzie TSA).

As part of the tactical and strategic planning applications, Goat HSM can be used to assess macro-level strategies to manage disturbance, hunting, and access. Goat HSM would also permit an evaluation of the overall risk/outlook for various groups or populations of goats, and the types of habitat that are limiting for each group or population.

In addition to the application of the tools to the Mackenzie TSA, more generalized products such as guidebooks could be developed to transfer general landscape management guidelines derived from the Goat HSM results to a broader geographic area.

1.6.3 Anticipated Users

The anticipated users or audience for the Goat HSM are:

- Forest Industry: Planners, engineers, and professional foresters in the preparation of operational plans that consider goats in site level decision-making regarding road location, block location, and timing of forestry activities.
- Statutory decision makers: Forest District Managers.
- Third party "auditors": Those who investigate issues of compliance, or forest certification.
- *Ad hoc* Committees: eg. LRMP biologist committee.
- General Public: Those reviewing strategic or operational development plans.
- Scientific community/technical experts: Those interested in new methods and application of techniques.
- Educational: Teachers at universities (especially University of Northern BC), and those carrying out extension activities to forest planners, etc.

2.0 METHODS

2.1 Overview of Goat HSM Activities

Initial Goat HSM development was accomplished through a collaborative effort during a series of three workshops held in February and March 2003 (Appendix A). Workshop participants included representatives from the forest industry, government ministries, and wildlife research groups. The workshop facilitator led scoping sessions designed to identify key factors and relationships relevant to mountain goat ecology and forestry activities. The discussions resulted in the development of 4 mountain goat habitat models, and 4 sub-models that describe management factors (included on enclosed disk). A trial application of the Goat HSM developed during the workshops was conducted using data from the lower Ospika River drainage (Appendix B). Project results were presented to stakeholders and the potential for further development and application of Goat HSM was discussed (Appendix C).

2.2 Modeling Approach

2.2.1 Building on the CHASE model

CHASE (Caribou Habitat Assessment and Supply Estimator) is a landscape- and forest stand-level habitat supply model developed to forecast the balance of northern caribou habitat and timber supply in the Mackenzie TSA (McNay *et al.* 2003). The Goat HSM project is an adaptation of the CHASE modeling framework, and was built on the principles, techniques, and experience that arose from development of CHASE.

2.2.2 Underlying Philosophy Regarding Modeling

All modeling activities contain an inherent philosophy. The philosophy used in this project is summarized in the following 3 general assumptions:

1. No model is going to be "the true or complete model", therefore it is important to formulate the model explicitly, incorporate empirical data and the recognition of uncertainty into the model, and make it adapt to new empirical information.
2. Alternatively, no finite amount of empirical data or science will form an exact characterization of the ecological situation or relationships, therefore it is important to develop a model that will bridge the gaps in the data and empirical understanding in order to create a more comprehensive and consistent, albeit hypothetical, understanding of the ecological system.
3. No model, will be readily implemented at the operations level; therefore it is important to incorporate an interpretive component into the overall project product.

An ideal model would be precise, general, and realistic, however one of these elements must be sacrificed if the other two are to be met. This modeling approach is built upon a desire for generality and realism and, as such, it would:

- Serve as a basis for communication regarding the causal relationships involved in the ecology of mountain goats and forest harvesting.
- Consider operational management factors relevant to the area.
- Incorporate data from fieldwork.
- Include a framework for analysis and decision-making.
- Consist of an open architecture for the evaluation of results (rather than a "black box" approach).
- Provide a mechanism for the choice of alternative adaptive management experiments that includes the consideration of costs ($ and social), uncertainty, sensitivity of the ecosystem, and the likelihood of getting reliable results.

2.2.3 Ecological Relationships Network

One of the goals of the project was to represent the ecological relationships relative to mountain goats in a way that was transparent (the actual ecological factors and relations were shown), and allowed the incorporation of both professional judgement and data. It was also important that the model could be built on a platform that was readily available, supported, and accessible to the modeling team (i.e., non-proprietary). The CHASE modeling team selected a Bayesian Belief Network (BBN) approach, using the modeling shell Netica® (Norsys Inc.), because it met these criteria and also enabled close co-operation with researchers and managers working on wildlife habitat supply models in Washington and Oregon (McNay *et al.* 2003, Marcot *et al.* 2001). The Goat HSM also adopted the BBN approach.

A BBN is a form of influence diagram which, as applied in ecology, depicts the logical or causal relations among ecological factors that influence the likelihood of outcome states of some parameter(s) of interest, such as forest condition or wildlife habitat. BBN's can be used to represent 'causal webs' of major influences, such as factors that most affect population abundance and distribution. BBN's have been used in a variety of applications in ecology and forest management. For example, the Interior Columbia Basin Ecosystem Management Project of the USDA Forest Service and USDI Bureau of Land Management have used numerous BBN models (Marcot *et al.* 2001).

BBNs also meet the objective of providing a useful communications medium that: (1) clearly displays major influences, and facilitates an explicit representation of how a system works; (2) combines categorical and continuous variables; (3) combines empirical data with expert judgment, often from multiple experts, and uses categorical, ordinal scale, and continuous data in the same model, (4) can be easily updated with new data and from expert review, and (5) expresses predicted outcomes as likelihoods as a basis for risk analysis and risk management (Marcot 1998).

Using the BBN approach entails: (1) identifying important ecological factors that contribute to habitat value or other factors of interest; (2) developing a "causal web" model that depicts how the ecological factors and management options influence the potential distribution and abundance of the species of interest; and (3) developing a set of probabilities that quantify those factors that influence species.

2.2.4 Aspects of Goat Ecology and Habitat Considered

In developing a conceptual representation (i.e., a model) of an ecological and management system it is impossible to include all known factors and relationships. The initial set of models included only the assumed "major" ecological relationships. These major factors were chosen because they were thought to have the most impact, are of key interest, have data available, and are currently within the realm of management action. In future model refinements additional detail can be included, and other factors and relationships included as needed.

Limiting factors for mountain goats are thought to include:

- Accidents – goats stay close to steep escape terrain; accidental fatal falls may occur.
- Avalanches – goats live on steep snowy terrain and are known to die in avalanches.
- Disease – goats are susceptible to disease like all wild ungulates.
- Predation – goats are effective anti-predator strategists, but are not immune to predation (goats are an alternate prey; changes in predator-prey relationships and abundance may impact goats).
- Starvation – goats have a generalist diet; they are not restricted by food requirements but predator avoidance takes precedence over forage availability; persistent heavy snowfall well into spring can prevent access to forage and result in starvation.
- Hunting – goats live in small populations; significant hunting has the potential to impact population viability, particularly if harvest is concentrated at mineral licks.
- Disturbance / Harassment – aircraft disturbance, industrial disturbance, and road/traffic disturbance can impact the whole goat population (direct impact, short-term); recreational activities may have long term impacts.

Disease transfer from domestic animals to mountain goats is not currently an issue of concern because there is no evidence to suggest that *Pasteurella* is transmitted between domestic sheep and mountain goats (B. Foreyt, University of Washington, pers. comm.), nor are there any domestic sheep grazing tenures in the Ospika valley or throughout the range of mountain goats in the Mackenzie TSA.

It is thought that predator avoidance (rather than forage availability) is the dominant factor in goat habitat use. Thus, proximity to escape terrain is considered to be important in all aspects of mountain goat habitat. The presence of steep, rough terrain is an important habitat feature common to natal areas, alpine summer range, alpine winter range, and forested habitats. Two models for escape terrain (summer and winter) can generally represent all four habitat types; each specific type can be distinguished as a sub-set of the general models by simple addition of 1 or 2 parameters unique to each (e.g., restricted to south aspects in winter).

Many mountain goat populations show high fidelity to low-elevation mineral licks. These licks and their associated access trails are used seasonally (April through October) by successive generations of goats. The licks themselves are thought to provide minerals that satisfy important physiological requirements of mountain goats. As such, low elevation licks and their access trails are considered to be important components of mountain goat habitat. Concerns have been raised regarding the potential impacts of forest harvesting activities on mountain goat populations using low elevation mineral licks in forested habitats.

Key components of goat habitat are specific geographic features (escape areas, licks, and trails). Consequently, unlike other types of habitat for other species, there is little opportunity to "rotate"

habitat or habitat use. Rather, the specific features must be managed and the impact of management activities assessed. This requires a modeling approach that can assess the impact of any specific management activity and also assess the cumulative impacts of activities occurring over time.

2.3 Modeling Tools

2.3.1 Defining Ecological Relationships

The ecological factors and relationships involved in determining mountain goat habitat values were represented using the BBN-based modeling software Netica® (Norsys Inc., http://www.norsys.com/)

The BBN approach using Netica® facilitated the effective development of habitat relationships in a workshop environment since it provided a relatively fast, interactive and easily understood visual structure for exploring factors, and allowed professional expertise to be used to array factors into a causal web even if quantitative, statistically-based information was lacking. Likewise, professional expertise was used to depict the probability structures of the degree to which various factors affect habitat or other variables of interest. In addition, relative sensitivity analysis can be conducted to determine the sensitivity of the outcome to various factors considered important. This approach allows different types of uncertainty to be explicitly acknowledged and evaluated.

2.3.2 Input (Attribute) Data Management

Data management that links modeling systems together and calculates stand and timber information and operational considerations was carried out using Microsoft Access® (Microsoft Inc.).

2.3.3 Spatial Data Handling

All spatial data handling and processing for Goat HSM was performed using ArcView® 3.2 (ESRI Corp.), either through custom computer programs (henceforth referred to as scripts) or the graphical user interface. This software was chosen for its low cost, portability, existing widespread use, advanced analysis functions, and ability to handle vector and raster data types.

Goat HSM used primarily a raster data model to store the spatial data and perform analyses. The raster data model divided the study area into 1-ha pixels, the result of laying a grid of rows and columns over the landscape. The advantages of raster data are the simple data storage structure and ease in performing spatial overlays and analyses.

2.4 Running the Models

The Goat HSM Users Guide (Hengeveld, in prep) is intended to provide an in-depth background to Goat HSM model tools, software, data requirements, and "run" procedures. Step-by-step operating instructions from data input to presentation of results will be described.

In order to have the model behave as realistically as possible, the starting point for all scenarios was the landscape situation (roads and cutblocks) as of 2002. For simplicitiy, planned roads and cutblocks are assessed, and results determined for each year over the life of the forest development / stewardship plan of interest (normally 5 years).

To demonstrate the capability of the models, a preliminary run of the Trails to Low Elevation Licks Model was completed using data from the lower Ospika River drainage study area (Appendix B).

3.0 THE MODELS

3.1 Overview of the Models Developed

The Goat HSM includes 4 management factors sub-models and 4 habitat models that have been developed as tools to predict the ecological value of habitat types used by mountain goats in the Mackenzie TSA.

The management factors sub-models describe factors identified as having the largest potential impact on mountain goats and goat habitat values. While many factors affect the survival of mountain goats, including forage availability, predation, disease, weather, and human impacts, the models include only those factors that are of current management concern and that can be managed or manipulated:

1. Ground disturbance (roads, traffic, machinery, human presence)
2. Aerial disturbance
3. Hunting of goats
4. Predation of goats

The habitat models were focused on habitat types considered most likely to be either limiting or important to mountain goat populations in the area, including:

1. Low Elevation Mineral Licks
2. Trails to Low Elevation Mineral Licks
3. Summer Escape Habitat
4. Winter Escape habitat

Throughout these models, reference is often made to "habitat", as in "habitat value" or "habitat preference". Habitat is defined to include three commonly stated requisites for survival of an individual: procurement of food, avoidance of predators, and the ability to undergo those activities without being displaced or excessively interrupted by human activity or management. One common resultant from each model is an estimate of habitat preference. Preference is deemed to occur any time an animal is located in a habitat type more frequently than would be expected from random locations (Chesson 1983). Another common resultant from each model is an estimate of habitat value, which incorporates the influence of disturbance impacts on the expected value of the habitat. Generally, the resultant from each model is determined by factors and relationships depending on a variety of primary ecological inputs or ecological correlates (Marcot *et al.* 2001) that can be measured or estimated in land-based inventories.

In the Strategy for Habitat Supply Modeling for British Columbia (Jones *et al.* 2002), 6 types of habitat supply models are identified. The Goat HSM fits within the category of "Single Species, Large Area Home Range, All/Most Life Requisites", however since it considers the interaction of predation it is, in some ways, also a multi species model.

3.2 Rationales for Management Factors Sub-Models

3.2.1 Ground Disturbance Sub-Model

Ground disturbance considers impacts from industrial activities (noise from heavy machinery), vehicular traffic (on roads crossing or adjacent to goat habitat), and human presence (on or near mineral licks, lick access trails, or escape terrain). These disturbances are primarily associated with forest harvesting, mining, and oil and gas exploration, although human presence can also result from recreational and research activities (hiking, hunting, forestry/wildlife research). Ground disturbances can result in both direct mortality (through vehicle collisions) and indirect mortality (avoidance of important habitat feature e.g. mineral lick/natal area/escape terrain, thus reduced energy or mineral intake resulting in poor reproduction and adult and/or kid survival). Geist (1971) states that disturbance can modify behaviour, thus impacting physiology, population productivity, and habitat use. Stress caused by human activities can also make goats more susceptible to disease (Joslin 1986).

The Ground Disturbance sub-model (Figure 1) feeds directly into the Mineral Lick and Trail habitat models. We considered a high degree of Ground Disturbance in the absence of any other factors (e.g. predation, hunting etc), to reduce the value of the habitat in question to 100% Moderate value habitat. The Ground Disturbance sub-model is combined with the Aerial Disturbance sub-model (see section 3.2.2) into a Total Disturbance sub-model which factors into the Summer Escape Terrain and Winter Escape Terrain habitat models.

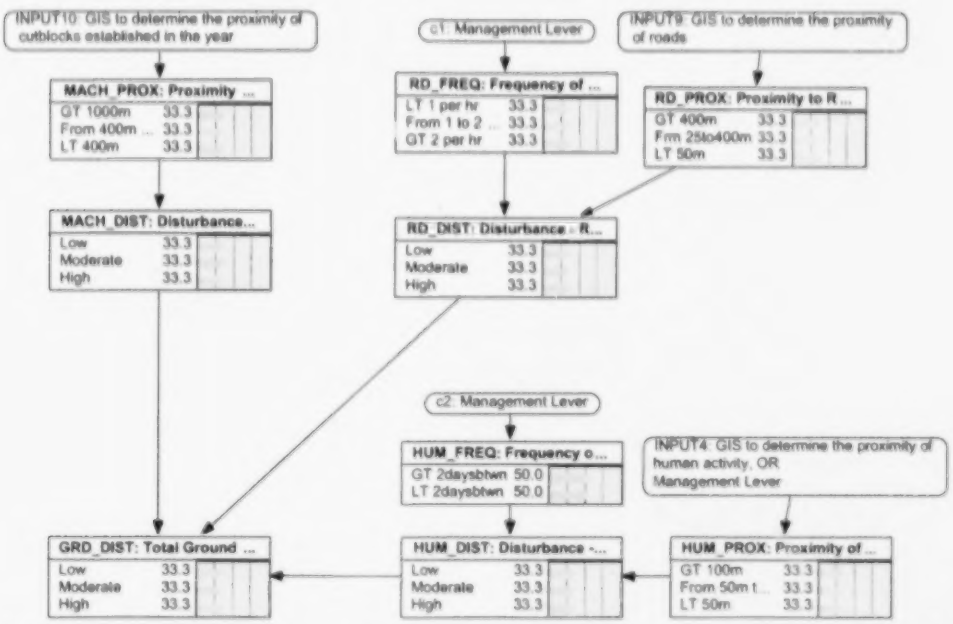

Figure 1. Factors and relationships contributing to total ground-based disturbance that may influence habitat use by mountain goats.

Industrial Disturbance Node (MACH_DIST)

Industrial disturbance includes noise emitted from heavy machinery or equipment used during road building, timber harvesting, mineral exploration, and well-site development. The factor considered most important for this sub-model was the proximity of this noise disturbance to goat habitat. Although we are unable to predict the exact location of the machinery, and the length of time the machine is working at that location, we assume that disturbance will be present if the general site (road, cutblock, well-site) is within a specific distance of goat habitat. The seasonal timing of the industrial activity is not an actual factor, but part of the input data to the model.

The few documented studies in the literature on the effects of industrial disturbance on mountain goats show conflicting results, although it appears that at least some level of negative effect is likely. Foster and Rahs (1981) documented temporary range abandonment by goats subjected to noise disturbance from drilling activity. Joslin (1986) noted no abandonment of ranges by goats subjected to seismic activities for energy exploration, however, the cumulative years of stress on the goats resulted in decreased population numbers and productivity. Foster and Rahs (1983) concluded that goats did not demonstrate any habituation to noise during the drilling activity period. However, through trials where goats were subjected to noise representative of gas exploration activities, Penner (1988) concluded that goats can habituate to continuous predictable noises. (He also noted however, that goats are disturbed by sudden unpredictable noises.) Goats in dense vegetation (i.e. along trails or near mineral licks) were found to exhibit more severe stress responses to noise than those on escape terrain (Foster and Rahs 1983), and females during the kidding and post-kidding periods were found to be sensitive to both predictable and unpredictable noises (Penner 1988).

Rationale for States

Machine Proximity Node (MACH_PROX):

Greater than 1000m from goat habitat (trail, lick, or escape terrain)
From 400 to 1000m from goat habitat (trail, lick, or escape terrain)
Less than 400m from goat habitat (trail, lick, or escape terrain)

- Distances refer to the proximity of roads built, cutblocks harvested, or well-sites drilled in the current year (i.e. where machinery is working) as determined by GIS analysis.
- Foster and Rahs (1983) noted a significant relationship between the distance of industrial disturbance and the level of goat stress response.
- Although Penner (1988) states that goats can habituate to continuous predictable disturbance (more typical of drilling rigs), the industrial disturbance our goats may be subjected to will not likely be continuous and predictable, specifically road building and harvesting operations where equipment is constantly moving to new locations.
- IWMS recommends that no roads or timber harvesting occur within 400m of a mineral lick used by goats, thus we adopted 400m as a critical threshold.
- We assume that the closer the noise disturbance is to goat habitat, the more impact there will be to the goat population. Machinery noise will likely be inaudible or at least relatively insignificant greater than 1 km away.

Road/Traffic Disturbance Node (RD_DIST)

Road/traffic disturbance includes any vehicular traffic along roads (primarily passenger vehicles to logging trucks, but can include ATV's), and can have both direct and indirect impacts on mountain goats. Collisions with vehicular traffic causing death directly impacts goat numbers, while consistent traffic and noise disturbance may indirectly affect goats by preventing or reducing their visits to important habitat (escape terrain, mineral licks, trails). As previously mentioned, goat response to noise disturbance is variable according to the literature. Singer (1978) states that goats using a mineral lick along a major highway habituated to both human visitors and trains, but still perceived vehicles as a threat. The unpredictable nature of vehicular traffic on logging roads suggests it is unlikely goats will habituate to this type of disturbance readily. The proximity and frequency of vehicular disturbance are the factors we considered most important to goats. Proximity is determined by GIS analysis, while frequency is considered as a management lever. The seasonal timing of vehicular disturbance is not an actual model factor, but part of the model input data.

Rationale for States

Road Proximity Node (RD_PROX):

Greater than 400m from goat habitat (trail, lick, or escape terrain)
From 50 to 400m from goat habitat (trail, lick, or escape terrain)
Less 50m from goat habitat (trail, lick, or escape terrain)

- Distances refer to the proximity of roads to goat habitat (as determined by GIS analysis).
- The closer the vehicular traffic is to goat habitat, the more likely direct mortalities will result from vehicle collisions.
- IWMS guidelines recommend no timber harvesting or road building occur within a 400m buffer around a mineral lick or WHA's.
- We assume that noise disturbance from vehicular traffic will be relatively insignificant beyond 400m from goat habitat.

Road Traffic Frequency Node (RD_FREQ):

Less than 1 vehicle per hour
From 1 to 2 vehicles per hour
Greater than 2 vehicles per hour

- Frequency refers to the number of vehicle passes (empty and loaded) on the road per hour.
- Frequency is included in the model as a management lever.
- Estimates may be based on wood volume or area harvested and transported down the road.
- The greater the frequency of vehicular traffic, the greater the risk of mortality to goats.
- Goats may be reluctant to cross a road to access other goat habitat if the frequency of disturbance is >2 trucks/hr.

Human Disturbance Node (HUM_DIST)

Human disturbance includes visits by humans near goat habitat primarily for the purposes of timber cruising, road and block layout, silviculture activities, research activities, and recreational activities. Mountain goats are generally known to be more alert and less readily approached than even mountain sheep (Geist 1978). It is unlikely that human visitation would cause permanent

abandonment of a habitat, but temporary abandonment, including deterring visits to mineral licks, is likely. The proximity and frequency of human disturbance are the factors we considered to be most important to goats; the seasonal timing of disturbance is not factor but part of the model input data. Proximity is determined by GIS analysis or is used as a management lever, while frequency is considered as a management lever.

Rationale for States

Proximity of Human Presence Node (HUM_PROX):

Greater than 100m from goat habitat (trail, lick, or escape terrain)
From 50 to 100m from goat habitat (trail, lick, or escape terrain)
Less 50m from goat habitat (trail, lick, or escape terrain)

- Distances refer to the proximity of human presence to goat habitat.
- We presume that human presence within 50 m of goat habitat would be most disturbing to goats.
- Beyond 50m, the presence of trees around licks and trails would provide a visual buffer and would lessen the impact of human presence, however, humans would likely be heard up to 100m away.
- Although the forested visual buffer may be lacking around higher elevation escape terrain and goats could detect humans much further away than 100m, the perceived threat is reduced since goats are on their escape terrain rather than in forested areas and thus less vulnerable.
- Human scent in the immediate habitat area may play a role in deterring use of that habitat by goats for a short period.
- Although goats may be able to habituate to human presence (Singer 1978), it is unlikely they would habituate to the sporadic, unpredictable types of human presence likely to be encountered in these more remote watersheds.

Frequency of Human Presence Node (HUM_FREQ):

Greater than 2 days between human visits
Less than 2 days between human visits

- Frequency refers to the frequency of human visits to goat habitat.
- Frequency is included in the model as a management lever.
- If goats avoid visiting an area for ~24 hrs after a human visit, then goats may potentially abandon that habitat if humans visit that area every day.

CPT Logic for Ground Disturbance Sub-Model

The ground disturbance sub-model was structured such that Industrial, Road/Traffic, and Human Presence disturbance types could be additive. The conditional probability table that was used to configure how the 3 disturbance types contribute to Total Ground Disturbance (GRD_DIST) was based on the following:

- Disturbance impact (GRD_DIST) increases with increased proximity and frequency of each activity.
- Road/Traffic disturbance has a slightly more negative impact than Industrial disturbance, and a much greater negative impact than Human Presence disturbance. Although likely

infrequent, the possibility of being killed in a collision with a vehicle slightly increases the negative impact of Road/Traffic disturbance over Industrial disturbance. The impact of Human Presence disturbance is much lower than both the other disturbance types due to the reduced duration and intensity of this type of impact.

- If Road/Traffic disturbance is determined to be HIGH due to the proximity and frequency of the activity, and Industrial and Human Presence disturbances are LOW, the resultant disturbance impact is 100% HIGH.
- If Industrial disturbance is determined to be HIGH due to the proximity of the activity, and Road/Traffic and Human Presence disturbances are LOW, the resultant disturbance impact is 90% HIGH and 10% MODERATE.
- If Human Presence disturbance is determined to be HIGH due to the proximity and frequency of the activity, and Road/Traffic and Industrial disturbances are LOW, the resultant disturbance impact is only 100% MODERATE.

3.2.2 Aerial Disturbance Sub-Model

The Aerial Disturbance sub-model (Figure 2) considers impacts of both rotary and fixed-wing flights over mountain goat habitat. These aerial activities are primarily associated with forest harvesting, mining, oil and gas exploration, heli-hiking, heli-skiing, and wildlife research. Mountain goats and mountain sheep (high elevation cliff-dwelling ungulates) are highly susceptible to aerial disturbance particularly by helicopters which have been demonstrated to elicit very strong stress responses (Horejsi 1976, Foster and Rahs 1981, Penner 1988, Bleich et al 1994, Cote 1996, Frid 1999). Over-flights by fixed-wing aircraft also cause disturbance to goats and sheep though to a lesser degree (Bleich et al 1994, Poole 1998, Frid 1999). Although our Aerial Disturbance sub-model includes both helicopter and fixed-wing disturbance types, over-flights by fixed-wing aircraft will rarely if ever rate as High Disturbance by default since:

1. They rarely fly within 500 m of the ground or cliff habitat;
2. They rarely remain in an area for >1 minute since they can not hover;
3. They rarely have reason to visit the same area on a repetitive daily basis.

The only exception to the rule may be fixed-wing radio-telemetry flights which require multiple passes at close range to obtain a positional fix on the radio-tagged goat, however, these flights are still likely to be relatively infrequent (1 flight weekly or biweekly on average). In contrast, helicopters (particularly those involved in heli-hiking or heli-skiing operations) may use the same flight paths on a regular and frequent basis, and have the ability to hover for long periods at close range to goat habitat. A number of negative consequences of helicopter disturbance have been reported for wild goats and sheep, many of which can affect reproduction and survival (Foster and Rahs 1983, Joslin 1986, Cote 1996, Frid 1998, 1999) including:

- Direct mortality (jumping off or falling off cliffs).
- Separation of females from young.
- Increased energy expenditures due to fleeing.
- Reduced energy intake (less time spent foraging, and/or more time spent close to escape terrain where less forage is available).
- Range abandonment (temporary or permanent).
- Increased susceptibility to disease resulting from chronic stress.

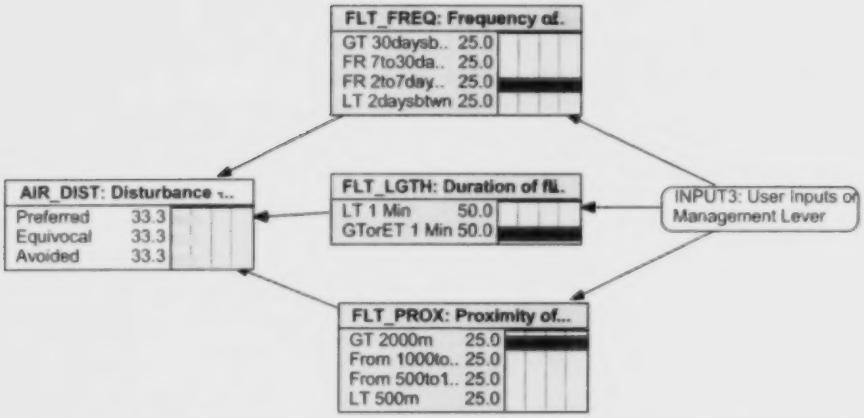

Figure 2. Factors and relationships contributing to total aerial disturbance that may influence habitat use by mountain goats.

Aerial disturbance was considered only in the Summer Escape Terrain (heli-hiking, research activities, industrial activities) and Winter Escape Terrain (heli-skiing, research activities, industrial activities) models. It is first combined with Ground Disturbance (see section 3.2.1) into a Total Disturbance sub-model. Aerial Disturbance is considered to have a significantly greater negative impact on goats than Ground Disturbance. HIGH Ground Disturbance in the absence of Aerial Disturbance results in a 100% Moderate impact to goats, however, HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact.

Aerial disturbance in the immediate vicinity of mineral licks and forested access trails was considered negligible. Heli-logging is unlikely to be used in harvesting low elevation forests on gentle terrain. Direct mortality is also unlikely since the response by goats would be to simply flee into the forest. Although Aerial Disturbance is included in the Escape Terrain models, there are no input data and it is not a dynamic factor (thus it is essentially trivial in a spatial-dynamic model). However, it is retained in the models to identify over-flights as an issue of concern. It is best considered as a "rule" (i.e., don't fly within 500 m of goat escape habitat) rather than a management lever.

Rationale for States

The impact of aerial disturbance on mountain goats on escape habitats is a function of the proximity, frequency, and duration of flights. The risk to goat populations caused by helicopters is reported to increase with increased frequency and duration of flights, and decreased proximity (Wilson and Shackleton 2001). We considered proximity to be of greater significance to goats based on studies that concluded that the most important factor affecting goat (or sheep) responses was the distance between the helicopter and the animals (Cote 1996, Foster and Rahs 1983, Frid 1998, 1999). The proximity, frequency, and duration of flights are used as management levers, or as user inputs.

Flight Proximity Node (FLT_PROX):

Greater than 2000m from escape terrain
From 1000 – 2000m from escape terrain
From 500 – 1000m from escape terrain
Less than 500m from escape terrain

- Goats exhibited movements or vigilant behaviours 85% of the time when helicopter approached within 500m (Cote 1996).
- Goats are rarely >500m from escape terrain thus any flight approaching within 500m laterally will likely have an impact.
- Goats will be more aware but will likely stay in same place during aerial approaches between 500 to 1,000m, whereas goats approached within 500m will likely walk or run along their escape terrain in an attempt to escape (greater chance of falling, greater stress).
- Rocky Mtn sheep often fled from a helicopter 1.6 km away (Horejsi 1976).
- 2 km is max. distance at which heli's begin to affect goat behaviour.
- intensity of response by Dall's sheep was negatively correlated with distance <3km (Frid 1998, 1999).
- studies have recommended a 2 km buffer around goat range to avoid aerial disturbance to goats (Foster and Rahs 1983, Cote 1996).
- Wilson and Shackleton's Interim Recommendations for Heli Operation Near Mountain Goats (Appendix 3 in Wilson & Shackleton 2001) recommended a 2 km buffer for helicopter activities near goat range.
- IWMS recommends 2 km limit for proximity of heli-logging to WHA's.
- Current provincial guidelines stipulate a minimum separation distance of 500m for existing heli-ski and heli-hiking tenures, and 2km for new tenures.
- We concluded that 2 km is the maximum distance at which aerial activity will affect goat behaviour, but that aerial activity within 500 m of goat habitat will cause significant disturbance to goats.

Flight Frequency Node (FLT_FREQ):

Greater than 30 days between flights
From 7 to 30 days between flights
From 2 to 7 days between flights
Less than 2 days between flights

- Days between flights rather than number of flights per week was considered to best represent flight frequency (E.G. 7 flights/week could mean once/day for 7 days, or 7 flights in one day, the latter having significantly more impact.
- Other studies have found that goats and sheep do not habituate to helicopter activity (Bleich et al 1994, Cote 1996, Frid 1999).
- Goats didn't habituate to sudden unpredictable noises (i.e. helicopters), only to consistent, predictable noise that was introduced gradually (Penner 1988).
- Foster and Rahs (1983) concluded that disturbance effects were additive – not only did they not habituate to disturbances but they became sensitized reacting even more strongly.
- We concluded that the more frequent the exposure to aerial disturbance, the more negative the effect on the goat population. We concluded that less than one flight per month would have a negligible effect on goats.
- Negative effects could be even more significant on goats on natal areas and winter ranges.

Flight Duration Node (FLT_LGTH):
Less than 1 minute in duration
Greater than or equal to 1 minute in duration

- Duration refers to the amount of time spent over the escape terrain (intended to distinguish between an "overhead hover" and a "fly-by").
- No literature was found that addresses duration of flight presence.
- We included 2 levels of duration: <1 minute (i.e. a passing of a helicopter or fixed-wing) vs. ≥1 minute duration (i.e. hovering or tight circling by helicopter) based on our assumption that aerial disturbance for greater than 1 minute has a prolonged and thus more negative effect on the goat population.

CPT Logic for Aerial Disturbance Sub-Model

The conditional probability table that was used to configure how flight *Frequency*, *Duration*, and *Proximity* interact to calculate the impact of Aerial Disturbance (AIR_DIST) was based on the following:

- Disturbance impact (AIR_DIST) increases primarily with increased proximity of aerial activity which is the factor of greatest significance to goats (Cote 1996).
- If Proximity is HIGH (<500m from escape terrain) but Frequency and Duration are both LOW impacts, the resultant impact is 50% HIGH and 50% MODERATE.
- Even the most intense Frequency (<2 days between flights) or Duration (>1 minute long) of flights has no impact if the Proximity of such flights is >2 km away. If either Frequency or Duration are determined to be HIGH, and all others factors are LOW, there is no impact (100% LOW impact).

3.2.3 Hunting Sub-Model

Hunting affects mountain goat populations both directly through the removal of goats, and indirectly through reducing the population's productivity (Smith 1988). Several factors render goat populations particularly sensitive to over-hunting (Eastman 1977, Hebert & Turnbull 1977, Adams & Bailey 1982, Swenson 1985, Smith 1988, Festa-Bianchet et al 1994):

- Late sexual maturity of adults.
- Low kid production and survival.
- High female harvest since difficult for inexperienced hunters to differentiate between the sexes.
- Importance of social structure – survival of yearlings and kids may be reduced if dominant nanny in family group killed; also, breeding success of dominant nannies is often higher.

Hunting mortality is considered additive to other types of mortality, and is blamed for goat population declines in many areas (Hebert and Turnbull 1977, Kuck 1977, Pendergast and Bindernagel 1977, Chadwick 1983, Phelps et al 1983, Smith 1988). When human access to goat populations is provided, populations previously in balance with other mortality factors can be rapidly depleted (Foster 1977, Kuck 1977, MacGregor 1977, Hoefs et al 1977, Pendergast and Bindernagel 1977, Adams and Bailey 1982, Chadwick 1983, Child and King 1991).

The 1988 Regional Wildlife Plan for the Omineca sub-region (Child and King 1991) acknowledged that hunter access in the Williston watershed in the late 80's was generally poor, and that most goat populations were still healthy and largely an "untapped resource". A potentially large degree of change was anticipated as logging roads extended northwards and into side drainages, particularly an increase in resident harvest of goats. The management objective for goats was to sustain a conservative level of annual harvest of 4 - 6% (Child and King 1991).

The Hunting sub-model includes guided, resident, and unregulated (subsistence and poaching) hunting, and pertains only to the Mineral Lick and Summer Escape Terrain habitat models. Although mineral licks are not typically targeted by hunters due to the sporadic nature of goat visits, goats can be concentrated at licks thus the potential for significant over-harvest of a local population is high. Access (primarily road proximity rather than road density) to low elevation mineral licks greatly increases the chance of this impact. A greater degree of hunting occurs in alpine goat summer range, with almost all guided hunts occurring in these areas. However, guided hunting is not typically related to road proximity thus it is not expected to increase with increased road proximity. In addition, goats are more accurately sexed during guided hunts resulting in fewer female goats harvested, thus guided hunting is considered to have a less significant impact on the goat population than resident and unregulated hunting. Proximity of roads to alpine goat range would however increase resident and unregulated hunting with the potential for significant local impacts. In addition, basic road deactivation will not prevent hunter access; only complete reclamation would be effective. HIGH Hunting impact in the absence of other factors (e.g. predation, ground disturbance) automatically reduces the value of the habitat in question to 100% Low Value habitat for goats.

The Hunting sub-model was not included in the Trails or Winter Escape Terrain habitat models. Since mineral licks are the endpoints of the access trails, and goats are more concentrated (spatially and temporally) at the licks than on the access trails, the impacts of increased goat harvest along trails is considered negligible. In addition, mineral lick trail locations would likely be largely unknown to hunters and would provide a much lower success rate than the licks themselves. An insignificant amount of poaching and subsistence hunting is thought to occur in winter, and on steep escape terrain.

Rationale for States

Based on the existing literature, we considered that proximity of roads to goat habitat (mineral licks or escape terrain) was the single most important factor affecting the degree of hunting (primarily resident and unregulated hunting), and that the degree of that hunting would have local population effects. We expect no increase in the level of hunting activity if roads are >2 km from goat habitat. The average resident hunter is thought to be deterred by distances >2 km; IWMS also recommends a 2 km management buffer around mineral licks. An increase of 0–3% hunting is expected when roads approach within 500 - 2,000 m of goat habitat (the area is more easily accessed by the average hunter), while an increase in local goat harvest of >3% is expected when roads or cutblocks are <500m from mineral licks or escape terrain. Access to within 500m of escape terrain actually places hunters right at the edge of goat summer range since goats are seldom found more than 500m from escape terrain. Providing a visual screen or buffer around goat habitat is not thought to be effective – the site will become known in time as local knowledge is shared, and the existing access will make the population vulnerable. Proximity of roads will be determined by GIS analysis.

Local Goat Harvest Node (HUNT):

No increase in local goat harvest
Local goat harvest increased by 0-3%
Local goat harvest increased by >3%

- The proximity of roads to goat habitat (as determined by GIS analysis) will determine the degree of increase in local goat harvest.
- This represents harvest over and above the current harvest level in absence of road access.
- The 1988 goat management objective for the Omineca Region was to sustain an annual goat harvest of 4-6% (Child and King 1991).
- Hebert and Turnbull (1977) recommended harvest levels of no more than 4% of a total goat population, or <5% of the adult goat population.
- Youds et al (1980) recommended goat harvest levels of 5% of the minimum population estimate for a given area.
- Conservative ungulate harvest levels are considered to be <10% (Child and King 1991).
- Assuming the local goat harvest is between 4–6%, an increase of 0-3% will still maintain the harvest within somewhat "conservative" levels, while an increase >3% is assumed to be detrimental.

3.2.4 Predation Risk Sub-Model

Goats typically exist at low densities, which combined with their effective anti-predator strategy of remaining within or near escape terrain, reduces their importance to predators as a major prey source (Geist 1971, Fox and Streveler 1986). However, changes in abundance of alternate prey species and consequently predators, can significantly affect goat populations. Primary mountain goat predators in our study area include wolves, grizzly bears, wolverines, eagles, and to a lesser degree, black bears. Although wolves are generally thought to prey on goats opportunistically (Smith 1986, Festa-Bianchet et al 1994), they can be a significant predator in areas of higher goat densities and/or few alternate large ungulates (Fox and Streveler 1986), and individual packs may even specialize on specific goat populations (Cote *et al.* 1997).

The presence of roads and cutblocks greatly influences the numbers and distribution of predators in an area. Bears use roads for travel and roadside feeding, and early seral cutblocks for summer foraging. Wolves use roads as year-round travel corridors, and they are attracted to the higher densities of ungulates (primarily moose) using early seral cutblocks for year-round forage. Bears may pose a higher risk to goats due to a greater chance of a random encounter at licks and along trails. Mineral lick access trails themselves might be more attractive to predators as travel corridors. Early seral habitats also favour a variety of prey species that support other potential goat predators, e.g., rabbits (lynx) and deer (cougars).

The Predation sub-model was considered in the Mineral Lick, Trails, and Summer Escape Terrain habitat models. In the Mineral Lick and Trails models, a HIGH Predation risk in the absence of other factors (e.g. ground disturbance, hunting) reduces the value of the habitat in question to 100% Low Value habitat for goats. Goats are more susceptible to predation when they are far from escape terrain, and in treed areas (Geist 1971, Rideout 1978, Festa-Bianchet et al 1994, Smith et al 1992, Cote and Beaudoin 1997). The ability of goats to detect predators in forested habitats is reduced, likely due to decreased visibility. Goats use treed areas for obtaining forage, to access low elevation mineral licks, and for snow interception in winter. In the Summer Escape Terrain model however, HIGH Predation risk only reduces the habitat value to 100% Moderate Value

habitat since predation poses a less significant risk to goats on escape terrain than to goats in forests. Predation was not considered to be a significant risk to goats on winter escape terrain since deep snows often preclude goats from venturing far from escape terrain.

Rationale for States

For our modeling purposes, we hypothesized that predation risk is correlated to the proportion of high value predator habitat present within a specified radial buffer around goat habitat. "High value predator habitat" is defined as habitat that provides year-round forage for alternate prey species, (primarily large ungulates) which in turn benefits predators, and for summer foraging by bears. This includes clearcuts and other early seral habitats on mesic or hygric sites with forest cover <40 years old. The presence of these moist, early seral habitats in close proximity to goat habitat can be is detrimental for goats.

Predation Risk Node (PRED):

Less than 10% of area within 2 km buffer is high predator habitat
From 10-30% of area within 2 km buffer is high predator habitat
Greater than 30% of area within 2 km buffer is high predator habitat

- The proportion of high value predator habitat within 2 km of goat habitat (as determined by GIS analysis) will determine the degree of increase in predation.
- We selected a 2 km radial buffer (roughly 1200 ha area) around each grid cell: this distance was considered reasonable in terms of a predators' ability to travel between high value predator habitat and mountain goat habitat.
- We identified 30% as the upper limit because if timber harvest is completed using a 3 pass rotation system then a maximum of 1/3 of an area could be harvested at a time. This amount of harvest would have a big impact with respect to early seral habitats, edge effects, etc.

3.3 Rationales for Habitat Models

3.3.1 Low Elevation Mineral Lick Habitat Model (LICK)

Low elevation mineral licks are typically used by mountain goats between April and November (Clare 2001, Demarchi *et al* 2001, Hebert and Turnbull 1977, McCrory *et al* 1977, Hebert and McTaggart-Cowan 1971). Goats rely heavily on mineral licks presumably to replenish sodium reserves that are flushed from the body due to the intake of potassium-rich green spring forage. Mountain goats show strong fidelity to specific mineral licks, and demonstrate traditional use over successive generations (Fox and Smith 1988). Valley bottom mineral licks can be up to 10 km from typical alpine summer escape terrain. This fidelity to mineral licks can render goats sensitive to disturbance from and displacement by various industrial activities (Hebert and McTaggart-Cowan 1971, Chadwick 1973, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to reduce or eliminate goat access to mineral licks, cause avoidance of licks by goats due to noise or traffic disturbance, create habitat conditions favourable for other prey species and consequently predators, and create access to licks for hunters. Removal of forested cover immediately adjacent to mineral licks is not thought to be of

significant concern compared to the previously listed factors. PWFWCP's Adaptive Management Trial in the lower Ospika River drainage (part of the larger Ospika Goat Project) is focusing on the impacts of forest harvesting on the use of mineral licks and their associated forest access trails by mountain goats (Wood and Hengeveld 2003). The project aims to determine differences, if any, in the timing, duration, and frequency of visits to low elevation mineral licks by radio-collared goats before and after forest harvesting. Data from the Adaptive Management Trial will be used to test the Low Elevation Mineral Lick model.

The Low Elevation Mineral Lick (LICK) habitat model (Figure 3) characterizes the factors that define low elevation mineral licks and that influence their use by mountain goats. Four primary factors are considered in this model: Lick Habitat Preference, Predation, Hunting, and Ground Disturbance, which feed into a final Lick Habitat Value node. Aerial disturbance was not considered in this model since aerial activity in the immediate vicinity of mineral licks was considered negligible. Heli-logging is unlikely to be employed in harvesting low elevation forests on gentle terrain. Direct goat mortality is also unlikely since goat response to aerial activity would be to simply flee into the forest.

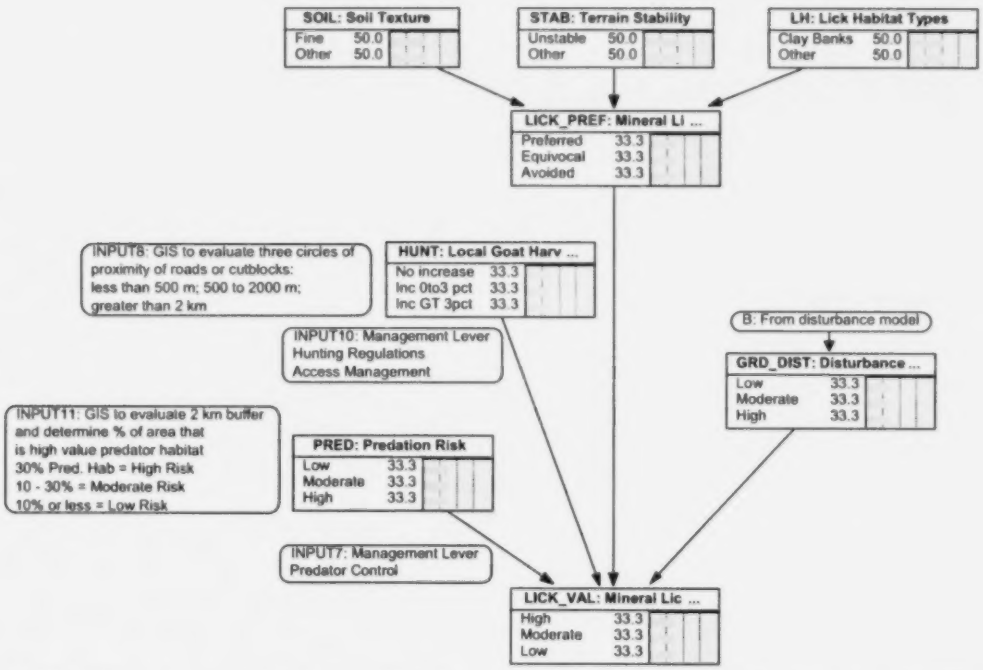

Figure 3. Ecological factors and relationships characterizing habitat value for low elevation mineral licks used by mountain goats.

The preference that mountain goats are expected to show for low elevation mineral lick habitats was based on access to appropriate mineral sources. The value of these low elevation mineral lick habitats is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the lick).
- Increased local goat harvest (due to the proximity of roads and cutblocks providing access to the lick).
- Increased ground-based disturbance (caused by industrial and human activity in proximity to the lick).

Habitat Preference Node (LICK_PREF)

The potential for an area to provide suitable mineral lick habitat for mountain goats is dependent on the presence of unstable (failed) slopes that are clay banks and/or have fine/lacustrine soils. These sites are defined by the physical attributes *Terrain Stability* (STAB), *Clay Banks* (LH), and *Soils* (SOIL). Identifying both clay banks and fine, lacustrine soils as important attributes appears to be a duplication, but both are considered because they are specified by separate data sources (forest inventory mapping and terrain stability mapping, respectively). Since the physiological importance of mineral licks to mountain goats is unclear according to the literature, mineral composition was not considered to be a useful criterion in defining mineral licks.

Rationale for States

Terrain Stability Node (STAB):
Unstable
Other

- Slope failures expose mineral soils, providing wildlife with access to minerals. Terrain stability mapping identifies failed slopes as 'unstable' habitat polygons.

Clay Banks Node (LH):
Clay bank
Other

- Clay banks are failed slopes that expose a clay mineral substrate. Clays contain fine-textured hydrous silicates of iron, manganese, magnesium, and other metals that may be of importance to mountain goats. Forest inventory (forest cover) mapping identifies 'clay banks' as unique habitat polygons. Mineral licks in the lower Ospika drainage were originally identified based on their designation as clay banks on forest cover maps. Subsequent field investigations found evidence of significant use by mountain goats of some but not all clay bank sites (M. Wood, pers. comm.).

Soils Node (SOIL):
Fine
Other

- Presumably fine soils provide an accessible source of minerals desired by mountain goats. Fine-textured soils may include lacustrine sediments, clays, mud, and silt; these are identified on terrain stability maps.

CPT Logic for Low Elevation Mineral Lick Habitat Preference (LICK_PREF)

The conditional probability table that was used to configure how the ecological factors of Terrain Stability, Clay Banks, and Soils interact to determine Low Elevation Mineral Lick Preference was based on the following:

- Unstable terrain was considered to be more important than either clay banks or fine soils; if terrain stability is determined to be "Other", the habitat preference is considered 100% Avoided.
- Unstable terrain combined with EITHER clay banks OR fine soils results in a Habitat Preference of 100% Equivocal.
- Unstable terrain combined with BOTH clay banks and fine soils results in 100% Preferred habitat.

Ground Disturbance Node (GRD_DIST)

See section 3.2.1 Ground Disturbance Sub-Model under Management Factors.

Local Goat Harvest Node (HUNT)

See section 3.2.3 Hunting Disturbance Sub-Model under Management Factors.

Predation Risk Node (PRED)

See section 3.2.4 Predation Risk Sub-Model under Management Factors.

CPT Logic for Low Elevation Mineral Lick Habitat Value Node (LICK_VAL)

The conditional probability table that was used to configure how Low Elevation Mineral Lick Habitat Preference, Ground Disturbance, Hunting, and Predation influence Low Elevation Mineral Lick Habitat Value (LICK_VAL) was based on the following:

- Predation Risk and Hunting are considered more significant than Ground Disturbance since they both have the ability to reduce actual populations through the direct removal of animals (not just through displacement).
- For Preferred Habitats, if Predation Risk OR Hunting is HIGH regardless of the influence of the other factors, the habitat value is automatically reduced to 100% Low value habitat.
- For Preferred Habitats, if Ground Disturbance is HIGH and other factors are low, the habitat value is only reduced to 100% Moderate value habitat.
- The maximum habitat value of any Equivocal habitat is 100% Moderate value.

Management Factors and Options

Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, and human presence to reduce impact of ground-based disturbance, predation, and hunting on mountain goats using low elevation mineral licks.

3.3.2 Trails to Low Elevation Mineral Licks Habitat Model (TRL)

Low elevation mineral licks are typically used by mountain goats between April and November, and are accessed using trails through forested habitats (Clare 2001, Demarchi *et al* 2001, Hebert and Turnbull 1977, McCrory *et al* 1977, Hebert and McTaggart-Cowan 1971). Goats rely heavily on mineral licks presumably to replenish sodium reserves that are flushed from the body due to the intake of potassium-rich green spring forage. Low elevation mineral licks can be up to 10 km away from alpine summer habitat (though most are probably within 5 km), and well-used trails worn down to mineral soil have resulted from traditional use of the same routes by successive generations of goats (Fox and Smith 1988). Trails seldom lead directly from summer habitat to low elevation licks but appear to be influenced by topography (following creek draws and ridges) and the presence of small areas of escape terrain referred to as "staging areas" (small rock outcrops, bluffs, cliffs). Goats are known to show strong fidelity to specific forested access trails. This fidelity to forested access trails leading to mineral licks can render goats sensitive to disturbance from and displacement by various industrial activities (Hebert and McTaggart-Cowan 1971, Chadwick 1973, Pendergast and Bindernagel 1977, Foster and Rahs 1983, Singer and Doherty 1985, Cote 1996, Shackleton 1999). Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to reduce or eliminate goat access to mineral licks, cause avoidance of trails due to noise or traffic disturbance, and create habitat conditions favourable for other prey species and consequently predators. Removal of forest cover immediately adjacent to trails is also of significant concern. PWFWCP's Adaptive Management Trial in the lower Ospika River drainage (part of the larger Ospika Goat Project) is focusing on the impacts of forest harvesting on the use of mineral licks and their associated forest access trails by mountain goats (Wood and Hengeveld 2003). The project aims to determine differences, if any, in the timing, duration, and frequency of visits to low elevation mineral licks by radio-collared goats before and after forest harvesting. The effectiveness of a 100m forested buffer on either side of a mineral lick access trail versus no buffer is being evaluated in this trial. Data from the Adaptive Management Trial will be used to test the Trails to Low Elevation Mineral Lick habitat model.

The Trails (TRL) habitat model (Figure 4) characterizes the factors that define mineral lick forested access trails and that influence their use by mountain goats. Three primary factors are considered in this model: Trail Habitat Preference, Ground Disturbance and Predation Risk, which feed into a final Trail Habitat Value node. Aerial disturbance was not considered in this model since aerial activity in the immediate vicinity of lick access trails was considered negligible. Heli-logging is unlikely to be employed in harvesting low elevation forests on gentle terrain. Direct goat mortality is also unlikely since goat response to aerial activity would be to simply flee into the forest. Hunting was also not considered to be a significant influence in this model. Since mineral licks are the endpoints of the access trails, and goats are more concentrated (spatially and temporally) at the licks than on the access trails, the impacts of increased goat harvest along trails is considered negligible.

The preference that mountain goats are expected to show for trails to low elevation mineral licks is based on access to appropriate mineral sources and stand age. The value of trails used to access low elevation mineral licks is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the trail).
- Increased ground-based disturbance (caused by industrial and human activity in proximity to the trail).

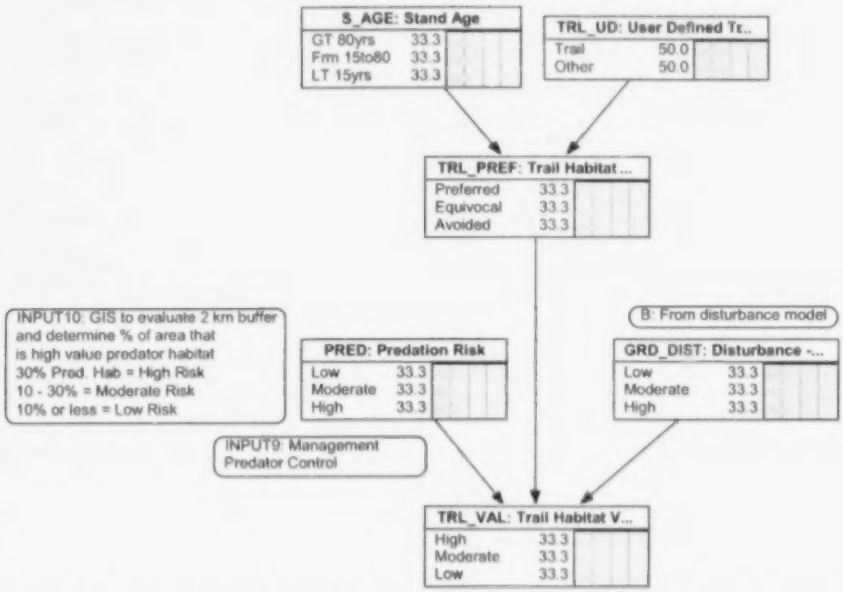

Figure 4. Ecological factors and relationships characterizing habitat value for trails to low-elevation mineral licks used by mountain goats.

Trail Habitat Preference Node (TRL_PREF)

Mineral lick access trail habitat preference is primarily a user-defined input to this model based on known trail locations to known goat mineral licks *(User Defined Trails*, TRL_UD). Trail preference is also influenced by *Stand Age* (S_AGE). Attempting to predict preferred trail locations using GIS has not been considered at this point. An attempt may be made to define trails in the future by using GIS to link known mineral licks through "staging areas" (though many of these are likely too small to identify on maps) to the nearest high elevation escape terrain. Input nodes will then feed the preference node rather than having just a single user-defined input. In terms of trail use, a goat might preferentially use one trail over another, and use a third trail equivocally, thus three states are identified (preferred, equivocal, avoided) for trail habitat preference. Trail preference may be identified / monitored by whether or not radio-collared goats are using the trail(s).

Rationale for States

User Defined Trails Node (TRL_UD):

Trail
Other

- Locations of access trails to known goat mineral licks in the lower Ospika drainage were originally identified by the PWFWCP in 1999 and mapped in 2000. Field investigations found evidence of significant use of the trails by mountain goats (M. Wood, pers. comm.). Typically only one primary access trail from alpine summer habitat to the mineral lick was located.

Stand Age Node (S_AGE):
LT 15 years
From 15 – 80 years
GT 80 years

- Stand age of greater than 80 years (mature forest) adjacent to access trails is considered preferential for goats. Young forests less than 15 years old would also provide some visibility, however stands between 15 – 80 years will result in poor visibility due to forest regeneration. Poor visibility may make goats more susceptible to predation. Stand age will be identified through Forest inventory (forest cover) mapping.

CPT Logic for Trails (to Low Elevation Mineral Licks) Habitat Preference (TRL_PREF)

The conditional probability table that was used to configure how the factors of User Defined Trails and Stand Age interact to determine Trail Habitat Preference was based on the following:

- If User Defined Trail is determined as "Other", habitat preference is 100% Avoided
- If Stand Age along a User Defined Trail is GT 80 years, the habitat is 100% Preferred
- If Stand Age is LT 15 years, the habitat is considered 50% Preferred and 50% Equivocal, and if Stand Age if between 15 – 80 years old the habitat preference is reduced to 50% Equivocal and 50% Avoided

Ground Disturbance Node (GRD_DIST)

See section 3.2.1 Ground Disturbance Sub-Model under Management Factors.

Predation Risk Node (PRED)

See section 3.2.4 Predation Risk Sub-Model under Management Factors.

CPT Logic for Trails to Low Elevation Mineral Licks Habitat Value Node (TRL_VAL)

The conditional probability table that was used to configure how Trails Habitat Preference, Ground Disturbance and Predation Risk influence Trail Habitat Value (TRL_VAL) was based on the following:

- Predation Risk has a higher impact on Trail Habitat Value than Ground Disturbance does due to the more direct impact in terms of potential goat mortality
- HIGH Predation Risk in Preferred Habitats automatically reduces the Trail Habitat Value to 100% Low value habitat.
- HIGH Ground Disturbance in Preferred Habitats (with LOW Predation Risk) only reduces the habitat value to 100% Moderate value habitat.
  - All Equivocal and Avoided Habitats are reduced to 100% Low Value Trail Habitat except Equivocal Habitats with LOW Predation and LOW Ground Disturbance (100% Moderate Value), and Equivocal Habitats with LOW Predation and MODERATE Ground Disturbance (50% Moderate, 50 % Low).

Management Factors and Options

Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, and human presence to reduce impact of ground-based disturbance and predation on mountain goats using trails to access low elevation mineral licks.

3.3.3 Summer Escape Terrain Habitat Model (SE)

The primary predator avoidance strategy of mountain goats is to use high elevation steep escape terrain. Predator avoidance exerts a significant influence on goat behaviour, and they seldom venture more than 500m from escape terrain to obtain forage. Steep escape terrain is used during the natal period for kidding, and throughout the summer. Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to significantly disturb goats on summer escape terrain, cause avoidance of preferred escape terrain due to noise or traffic disturbance, create habitat conditions favourable for other prey species and consequently predators nearby, and create access to summer goat habitat for hunters.

The Summer Escape Terrain habitat model (Figure 5) characterizes the factors that define summer escape terrain habitats and that influence their use by mountain goats. Four factors are considered in this model: Summer Escape Terrain Habitat Preference, Total Disturbance (a combination of Ground and Aerial Disturbance), Hunting, and Predation Risk, which feed into a final Summer Escape Terrain Habitat Value node.

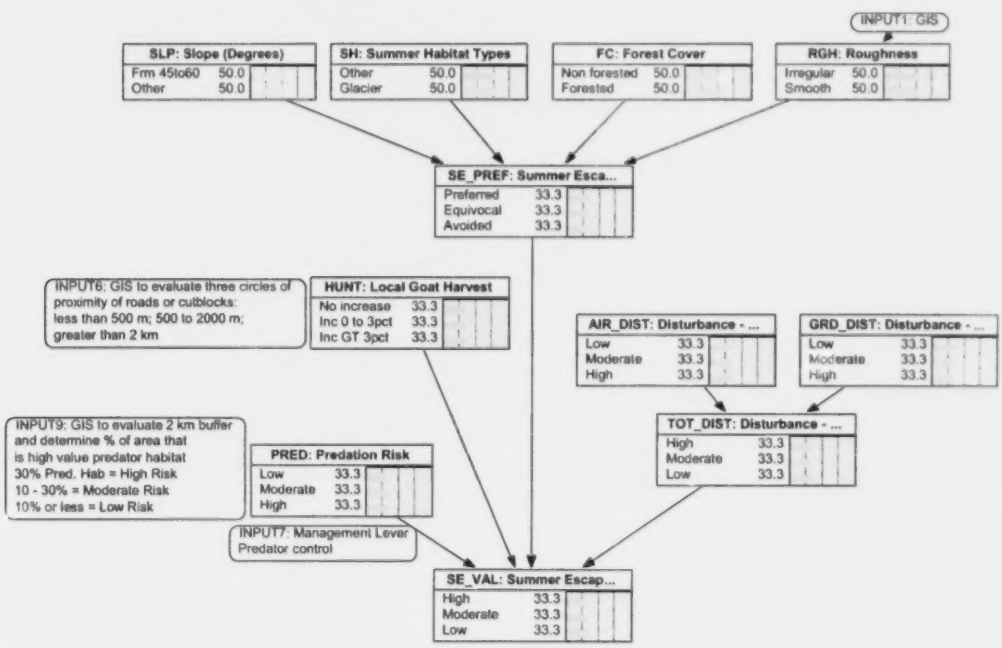

Figure 5. Ecological factors and relationships characterizing mountain goat summer escape habitat value.

The preference that mountain goats are expected to show for summer escape terrain is based on the presence of steep, rough, non-forested habitats (exclusive of glaciers). The value of summer escape terrain is reduced by:

- Increased predation risk (a function of the amount of high value predator habitat within a 2km radius of the trail)
- Increased local goat harvest (due to the proximity of roads and cutblocks providing access to the escape habitat).
- Increased total disturbance (ground-based disturbance caused by human activity in proximity to the escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights)

Summer Escape Terrain Habitat Preference Node (SE_PREF)

The potential for an area to provide suitable summer escape terrain for mountain goats is dependent on the presence of appropriate conditions of *Slope* (SLP), *Forest Cover* (FC), and *Roughness* (RGH), and *Summer Habitat Type* (SH).

Rationale for States

Roughness Node (RGH):
Irregular
Smooth

- Roughness is considered because slope alone isn't enough to gauge high value habitat. Roughness provides ledges for cover and travel, and also reduces the risk of avalanches (relative to smooth terrain). Roughness will be assessed using a GIS script with Arcview Spatial Analyst to assess variation in local topography. Using TRIM data, changes of 20-30 degrees within 100 m of a 25m grid cell will be assessed, and coupled with a steepness rating.

Slope Node (SLP):
From 45 – 60 degrees
Other

- A fundamental characteristic of mountain goat escape terrain is moderate to steep slope.

Forest Cover Node (FC):
Non-forested
Forested

- Typical escape terrain is primarily non-forested. 'Non-forested' includes alpine, subalpine parkland, non-productive brush.

Summer Habitat Type Node (SH):
Other
Glacier

- Any habitat type may be used, exclusive of glaciers.

CPT Logic for Summer Escape Terrain Habitat Preference (SE_PREF)

The conditional probability table that was used to configure how the Slope, Forest Cover, Roughness, and Summer Habitat Type interact to determine Summer Escape Terrain Habitat Preference was based on the following:

- Any habitat defined as Forested, Smooth, or as a Glacier, regardless of slope, automatically reduces the preference of that habitat to 100% Avoided
- Steep, Non-Forested, Irregular habitats exclusive of glaciers are 100% Preferred summer escape terrain habitats

Total Disturbance Node (TOT_DIST)

Total disturbance includes ground-based disturbance caused by human activity in proximity to summer escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights near summer escape habitat.

See sections 3.2.1 Ground Disturbance Sub-Model, and 3.2.2 Aerial Disturbance Sub-Model for details pertaining to each sub-model.

CPT Logic for Total Disturbance (TOT_DIST)

The conditional probability table that was used to configure how Aerial Disturbance (AIR_DIST) and Ground Disturbance (GRD_DIST) influence Total Disturbance was based on the following:

- The impact of Aerial Disturbance is considered to be greater than Ground Disturbance on summer escape terrain due to the potential of causing direct goat mortality, and the very strong stress responses of goats elicited by aircraft
- HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact on summer escape terrain
- HIGH Ground Disturbance in the absence of Aerial Disturbance results in only a 100% Moderate impact on summer escape terrain

Local Goat Harvest Node (HUNT)

See section 3.2.3 Hunting Disturbance Sub-Model under Management Factors.

Predation Risk Node (PRED)

See section 3.2.4 Predation Risk Sub-Model under Management Factors.

CPT Logic for Summer Escape Habitat Value Node (SE_VAL)

The conditional probability table that was used to configure how Summer Escape Habitat Preference, Total Disturbance, Hunting, and Predation Risk interact to determine Summer Escape Habitat Value to mountain goats was based on:

- Hunting and Total Disturbance have equal and greater impacts on Summer Escape Habitat Value than Predation
- Predation Risk is considered to be lower since goats on steep escape terrain are more difficult to capture (compared to when in forested habitats)
- HIGH Hunting OR HIGH Total Disturbance on Preferred Habitats regardless of other factors automatically reduces the Summer Escape Terrain Value to 100% Low value habitat.
- HIGH Predation, combined with LOW Hunting and LOW Total Disturbance on Preferred Habitats, only reduces the habitat value to 100% Moderate value habitat.

Management Factors and Options

Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, human presence, and aerial traffic, to reduce impact of ground and aerial disturbance, hunting, and predation on mountain goats using summer escape terrain.

3.3.4 Winter Escape Terrain Habitat Model (WE)

The primary predator avoidance strategy of mountain goats is to use high elevation steep escape terrain. Predator avoidance exerts a significant influence on goat behaviour, and they seldom venture more than 500m from escape terrain to obtain forage. Although high elevation steep escape terrain near windswept slopes are commonly used by goats in winter, steep escape terrain surrounded by forested habitat at lower elevations are also preferred. Forested habitat in close proximity to steep, rough terrain, provides both snow interception and forage availability. Stands that support arboreal lichens and are tall enough for snow interception are favourable. Through timing, proximity, and frequency, industrial development (forestry, oil and gas) has the potential to significantly disturb goats on winter escape terrain, particularly mid-elevation winter ranges, and cause avoidance of preferred escape terrain due to noise or traffic disturbance.

The Winter Escape Terrain habitat model (Figure 6) characterizes the factors that define winter escape terrain habitats and that influence their use by mountain goats. Two factors are considered in this model: Winter Escape Terrain Habitat Preference, and Total Disturbance (a combination of Ground and Aerial Disturbance), which feed into a final Winter Escape Terrain Habitat Value node. Hunting was not considered to be a significant influence in this model since only unregulated (subsistence and poaching) hunting would occur in winter. Given the nature of the steep, rough terrain that goats typically use during winter, combined with the presence of snow, would likely preclude most unregulated hunting from occurring. Predation was also excluded from this model. Predation of goats residing on steep, snow-bound winter escape habitats by wolves is also likely to be relatively unsuccessful. Predation by wolverines may be somewhat more significant, however, the predation risk is assumed to be a constant and independent of human activity thus difficult to manage or monitor. Snowmobiling was also not considered an activity of significant impact to goats due to the steep nature of goat winter escape terrain.

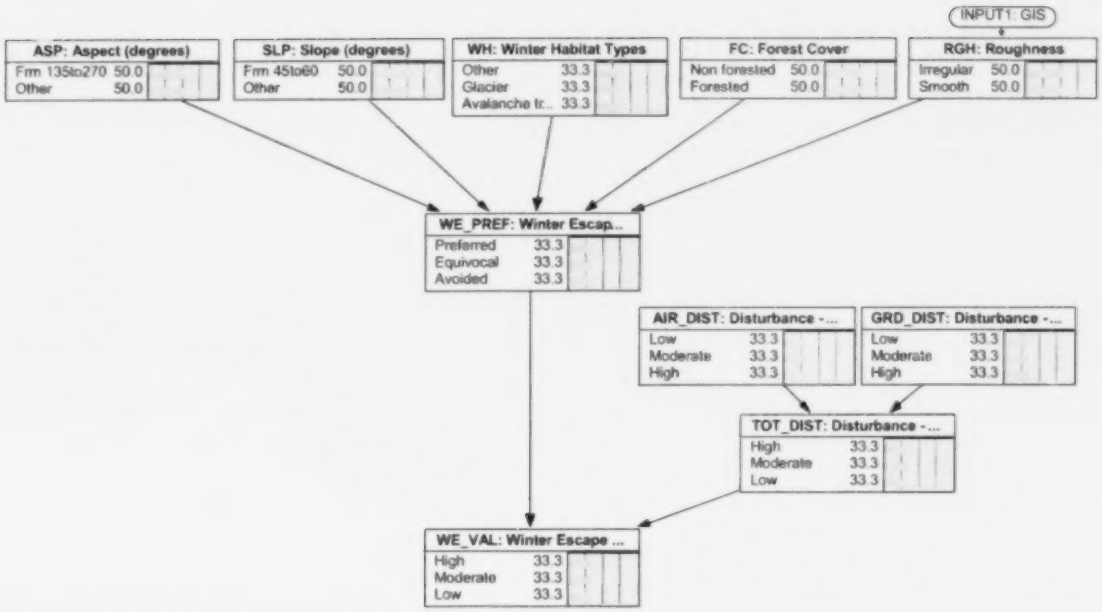

Figure 6. Ecological factors and relationships characterizing mountain goat winter escape habitat value.

The preference that mountain goats are expected to show for winter escape terrain is based on the presence of steep, south-facing, rough, non-forested habitats (exclusive of glaciers or avalanche chutes). The value of winter escape terrain is reduced by:

- Increased total disturbance (ground-based disturbance caused by human activity in proximity to the escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights)

Winter Escape Terrain Habitat Preference Node (WE_PREF)

The potential for an area to provide suitable winter escape terrain for mountain goats is dependent on the presence of appropriate conditions of *Slope* (SLP), *Aspect* (ASP), *Forest Cover* (FC), and *Roughness* (RGH), and Winter *Habitat Type* (WH).

Rationale for States

Slope Node (SLP):

From 45 – 60 degrees
Other

- A fundamental characteristic of mountain goat escape terrain is moderate to steep slope.

Aspect Node (ASP):
From 135 – 270 degrees
Other

- Preferred aspects in winter offering increased solar radiation range from SE to W.

Forest Cover Node (FC):
Non-forested
Forested

- Typical escape terrain is primarily non-forested. 'Non-forested' includes alpine, subalpine parkland, non-productive brush, etc.

Roughness Node (RGH):
Irregular
Smooth

- Roughness is considered because slope alone isn't enough to gauge high value habitat. Roughness provides ledges for cover and travel, and also reduces the risk of avalanches (relative to smooth terrain). Roughness will be assessed using a GIS script with Arcview Spatial Analyst to assess variation in local topography. Using TRIM data, changes of 20-30 degrees within 100 m of a 25m grid cell will be assessed, and coupled with a steepness rating.

Winter Habitat Type Node (WH):
Other
Glacier
Avalanche Track

- Any habitat type may be used, exclusive of glaciers and avalanche tracks in winter.

CPT Logic for Winter Escape Terrain Habitat Preference (WE_PREF)

The conditional probability table that was used to configure how Slope, Aspect, Forest Cover, Roughness, and Winter Habitat Type interact to determine Winter Escape Terrain Habitat Preference was based on the following:

- Any habitat defined as Gentle Slope, Forested, Smooth, or as a Glacier or Avalanche, automatically reduces the preference of that habitat to 100% Avoided
- Steep, Non-Forested, Irregular habitats exclusive of glaciers and avalanches on SE to W facing aspects are 100% Preferred winter escape terrain habitats
- Steep, Non-Forested, Irregular habitats exclusive of glaciers and avalanches on Other aspects are reduced to 50% Preferred and 50% Equivocal winter escape terrain habitats

Total Disturbance Node (TOT_DIST)

Total disturbance includes ground-based disturbance caused by human activity in proximity to winter escape habitat, and aerial disturbance caused by helicopter and fixed-wing over-flights near winter escape habitat. See sections 3.2.1 Ground Disturbance Sub-Model, and 3.2.2 Aerial Disturbance Sub-Model for details pertaining to each sub-model.

CPT Logic for Total Disturbance (TOT_DIST)

The conditional probability table that was used to configure how Aerial Disturbance (AIR_DIST) and Ground Disturbance (GRD_DIST) influence Total Disturbance was based on the following:

- The impact of Aerial Disturbance is considered to be greater than Ground Disturbance on winter escape terrain due to the potential of causing direct goat mortality, and the very strong stress responses of goats elicited by aircraft
- HIGH Aerial Disturbance in the absence of Ground Disturbance results in a 100% High impact on winter escape terrain
- HIGH Ground Disturbance in the absence of Aerial Disturbance results in only a 100% Moderate impact on winter escape terrain

CPT Logic for Winter Escape Habitat Value Node (WE_VAL)

The conditional probability table that was used to configure how Winter Escape Habitat Preference and Total Disturbance interact to determine Winter Escape Habitat Value to mountain goats was based on:

- HIGH Total Disturbance on Preferred Habitats automatically reduces the Winter Escape Terrain Value to 100% Low value habitat.

Management Factors and Options

Manage frequency, proximity, and timing of industrial activity, road proximity and vehicle traffic, human presence, and aerial traffic, to reduce impact of ground and aerial disturbance on mountain goats using winter escape terrain.

4.0 RESULTS AND INTERPRETATIONS

4.1 Presentation of Results

As described in section1.6 of this report, the Goat HSM can be used for operational and strategic level planning. While specific applications of the goat model will likely vary, there are a number of results that will likely be of interest in most applications. These typical results have been developed into "standard" products in the form of posters that depict the amount and spatial distribution of the range types (by habitat value classes) over time. The type of questions to be assessed in the interpretation of results is presented in section 4.2. The "standard" model results can be applied to typical management decision-making. Additional applications of the model will be explored in future model development.

To demonstrate the capability of the models, a preliminary run of the Trails to Low Elevation Licks Model was completed using data from the lower Ospika River drainage study area. Results have been used to test the presentation format to determine what information and formats are most useful.

Two formats were used to present the model results:

1. Digital versions of the maps for each habitat-type modeled (Low Elevation Mineral Licks, Trails to Low Elevation Licks, Summer Escape and Winter Escape) can be produced in annual time steps for the duration of the model analysis period (5 year development plan). For demonstration purposes, maps were generated for one specified time (2002) for the Trails to Low Elevation Licks model and its associated management factors sub-models. For each node in the model that has spatial data output, maps were produced in ArcView and then exported as an image in jpeg format (see map products in Appendix B).
2. Tables were produced to show the total areas (km^2) by state value for each of the final output nodes of the models.

Maps and tables were compiled and posters produced for presentation. A format for the presentation of results was developed for each of the habitat types and factors of interest in the model. Posters depicting results from a run of the Trails to Low Elevation Licks are presented in Appendix B.

4.2 Evaluation and Interpretation of Model Results

4.2.1 General Evaluation and Interpretation Criteria

Model interpretations are guided by questions of interest to resource managers. The following 7 questions were identified as a focus for general model interpretations:

1. How much of each range type (by habitat value class – preferred, equivocal, avoided) will there be in a management area?

- This can be evaluated quantitatively from tables of the area (ha) of each habitat value class (where applicable). In addition, this can be evaluated visually by looking at the maps.

2. How have the amounts of each range type changed over the time horizon of the model?
   - This can be evaluated by comparing the area of each range type (by habitat value class where applicable) over time using the tables provided.

3. How has the overall spatial distribution of each range type changed across the management area over time?
   - Although there are a number of possible statistical ways of presenting distribution information, at this time a visual scan of the maps is considered the best evaluation technique (maps are available for annual timesteps of the model and can be run as a "movie" to see changes in distribution of habitats over time). If there are areas of concern regarding distribution of habitat then these can be explored in more detail.

4. How does the amount of habitat in each range type compare with what might be possible under a management regime designed to optimize the amount of the range type?
   - In order to evaluate the "capability" of the area with respect to the various range types, a map with no reduction of habitat value from management activities is presented for comparison. This depicts the maximum amount of habitat (usually the high habitat value class) that would be available if there were no reduction of habitat value due to any of the management factors.

5. As the amount of habitat (by value class in each range type) changes, when should managers become concerned?
   - The proposed approach to determining important or critical changes in habitat is via a set of "red flags" – a set of criteria that would indicate significant events in the predicted future supply of habitat. This raises the question of what magnitude of change constitutes a red flag. Since so little is known regarding goat habitat relations the precautionary principle is recommended. The following types of red flags are proposed for discussion as the Goat HSM is further developed:
     i. When the amount of the preferred habitat value class of any range type changes.
     ii. When the preferred mineral lick habitat is reduced to equivocal or avoided, since mineral licks are scarce and are specific features that appear to be "irreplaceable" if impacted by management.
     iii. When preferred trail habitat is reduced to avoided, since trails link escape and lick habitat and appear to be used traditionally. A reduction of preferred trail habitat to equivocal is a yellow flag since other routes might be used.
     iv. When 30% of preferred winter escape habitat is reduced to avoided since winter escape habitat is a potentially significant factor in winter goat survival (although, this type of habitat is relatively more abundant than licks or trails). If 50% is reduced to equivocal then this is a yellow flag.
     v. When 50% of preferred summer escape habitat is reduced to avoided since summer escape habitat is likely the most abundant range type and unlikely to be limiting. If 50% is reduced to equivocal then this is a yellow flag.

6. Is the amount of one range type limiting the numbers of goats (i.e. the limiting factor)? If so, which range type is limiting? If one range type is limiting, and others are in "abundance"

does this mean that the abundant range types can be managed "down" to levels that support the numbers of goat supported by the limiting range type?

- It is likely that one range type is limiting population numbers, however this hasn't been determined in the model as yet. It is likely that the number of goats that can be supported is limited by one type of habitat that is less abundant. Specific interpretations for individual range types are further developed in section 4.2.2.

7. How is the amount of habitat in each range type linked to the numbers of goats?
   - This question cannot really be answered without considering whole population level responses. Follow-up modeling regarding whole population response to habitat changes could address the question of the carrying capacities of the range types and consequently the linkage of habitat change to population change.

4.2.2 Evaluation and Interpretation of Specific Model Results

The Goat HSM workshop participants intend to develop criteria for model evaluations and interpretations based on the results of the specific goat habitat models.

5.0 MODEL TESTING

5.1 The General Approach to Testing

Protocols for reporting, testing, and accrediting habitat supply models in B.C. do not exist. This lack of procedure is likely in part due to philosophical debate on the proper use of models, and hence how testing might proceed. Testing should consider the context under which the model is intended to be used. For example, a standard and accepted, or valid, modeling technique may be completely inappropriate when applied to a set of modeling goals that differ for the ones the model was designed to address. Most people using habitat supply models acknowledge the goal generally as an aid to making decisions about resource management and not as a calculation to predict outcomes of management actions (i.e., strategic rather than operational). Hence, a major conclusion about assessing habitat supply models generally should simply be whether the model is effective in achieving the overall goals. Using "effectiveness" as a part of model testing embraces the commonly expressed, general characteristic of models – no model is correct but some are useful (e.g. useful as an aid in making decisions about management).

Nevertheless, demand for more technical model testing remains strong. For example, the suite of models fundamental to the Timber Supply Analysis in British Columbia form the basis for an important provincial policy that has important and widespread economic implications on site-specific management around the province. It is proposed that the Goat HSM undergo testing and review to the extent that it achieves at least the same credibility as the TSR models. Presumably, a credible model is one that is judged to be effective and has strong technical merits. Technical testing of models has given rise to a number of terms that are sometimes used indiscriminately. The plan for testing the Goat HSM focuses on the following:

- Effectiveness, where the primary concern is whether applications are determined generally to be useful and advantageous;
- Validation, where relationships used in the model are determined to have some empirical evidence to support or justify the use of the relationship;
- Calibration, where validated relationships are used in a way that is judged to be suitable for the specific application.

Some discussions regarding model testing refer to the terms verification or veracity; here these terms are considered redundant with the process of validation and calibration.

5.2 Effectiveness: Determining the Degree of Success in Applying the Goat Model

Fundamentally, the most important test of the Goat HSM is whether the tool is determined to be effective or useful as an aid to managing forests in a manner that maintains the sustainable supply of habitat for goats and if, by using the tool for that purpose, goat populations remain healthy. Because this result cannot be measured quickly (or perhaps even precisely), effectiveness must be judged on the basis of other, more measurable results; some of which are technical (discussed in 5.3) and some of which are not. The non-technical results are simply to confirm that the goat model meets the following of the goals originally targeted:

- It is commonly accepted as addressing a high priority resource management issue;

- It provides the necessary functional links among inventory, policy, and management (i.e., has a functional feedback from management to policy, with appropriate indicators that are measurable through a monitoring protocol);
- It is adaptable (i.e. easy to update with new information about basic resources or relationships);
- The ecological relationships used and the associated assumptions are made explicit; and
- It is used and is usable (i.e., gains a track-record for being used) to address Operational plans (Forest Stewardship Plans); and is relatively easy to run and interpret.

One key goal of the Goat HSM, for example, was to make one common set of explicit rules for habitat management available to all stakeholders. If the Goat HSM was effective at this, then management decisions would become easier to make and presumably, more consistent across jurisdictional boundaries and among resource managers.

5.3 Validation and Calibration: Determining the Degree of Technical Merit

Future supply of habitat and the health of goat populations are essentially a theoretical construct insofar as monitoring is concerned. The Goat HSM develops indicators of these constructs through the modeling process. These are likely to be used as indicators at an operational level. For this reason, all ecological relationships within the Goat HSM need to be valid and calibrated to the region of application. Validation should address at least the following two major assumptions:

1. Are the assumptions valid?
   - An explicit list of assumptions and their implications should be available for review.
   - Assumptions should not over-ride applicability or usefulness of results.

2. Are the relationships measurable and accurate?
   - Dependant and independent variables are defined in measurable units.
   - Outputs are consistent with observations (i.e., >50% of variance explained by the independent variables, 9 times out of 10).
   - Outputs are tested against independent predictions (e.g., ancillary information supports the logic of primary predictions, predictions remain robust in new applications).

The task of validation is to be conducted on the Goat HSM as a future phase of model development.

5.3.1 Opportunities for Using Empirical Data to Update the Goat Model

The Goat HSM was constructed in a way that ensured both the model inputs and the model results could be measured and monitored. Furthermore, although data collection associated with the Ospika Goat Project was independent of the modeling, it was designed to be a set of data that could be used to assess the model relationships. This association between modeling and fieldwork has been referred to as "model-motivated data collection" after Turchin (1998). To the extent possible, data collected as part of the Ospika Mountain Goat Project will be used to assess the validity of ecological relationships.

5.3.2 Opportunities to Design Tests of the Goat Model: Adaptive Management

Adaptive management is defined to mean a systematic process for continually improving forestry policies and practices by learning from the outcomes of operational programs. The process typically includes the following 6 steps (Taylor and Nyberg 1999):

1. Assessing the problem or opportunity to be investigated;
2. Designing a management approach that achieves resource goals and also advances learning about how to improve management in the future;
3. Implementing the management approach in operational, not research, settings;
4. Monitoring the outcomes;
5. Evaluating the results to determine if they match forecasts made at the design stage; and
6. Adapting future management decisions to incorporate what was learned.

Adaptive management (AM) can take two forms: passive and active. In passive AM, a policy or prescription for goats would be implemented, outcomes would be monitored and evaluated, and the policy would be modified as necessary to increase its success in the future. This cycle might be repeated numerous times.

In active AM, two or more policy alternatives (e.g., different sets of operational regimes at the stand level) would be implemented in different areas to compare their success. Again, results would be monitored and evaluated, and the preferred policy would be selected based on the results of the management experiment[1].

The Ospika Mountain Goat Project offers several opportunities for both passive and active AM in which the Goat HSM may be useful:

- The current active AM trial in the lower Ospika R drainage (Wood and Hengeveld 2003)
- Other possible AM projects for goats in the Mackenzie TSA
- Sensitivity analyses to prioritize research and field work aimed at improving understanding of key relations

[1] Throughout this section, "experiment" means a test of an unproven technique or policy and does not imply the use of the full rigor normally expected of scientific experiments. All policies and practices to be tested through AM are recognized as experiments in this broad sense, because their outcomes can not be predicted with confidence.

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APPENDIX A. MODELING WORKSHOP AGENDAS AND SUMMARIES

The Ospika Mountain Goat Project

Goat Mineral Lick Habitat Supply Modeling Workshops

Workshop #1 – Monday February 3rd through Wednesday February 5th
Start time 1:00 pm Monday
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Workshop #2 – Tues February 18th through Thurs February 20th (tentative)
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Workshop #3 – Mon March 3rd and Tues March 4th (tentative)
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Workshop #4 – Tues March 18th and Wed March 19th (tentative)
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Please RSVP to confirm your interest and participation in these workshops.
Contact Pamela Hengeveld *Tel.* 250-997-5700 pamatwildinfo@cablerocket.com

Slocan Forest Products – Mackenzie Operations is hosting a series of 4 workshops in February and March 2003 to initiate development of a Habitat Supply Model for mountain goats.

The intent of the workshops is to construct a preliminary, Netica©-based (http://www.norsys.com/) Mineral Lick Habitat Supply Model to address concerns of habitat supply and alternative mineral sources for mountain goat (*Oreamnos americanus*) populations potentially impacted by forest harvesting. The Mountain Goat Mineral Lick Habitat Supply Model is to be completed by 31 March 2003, as the initial step in developing a formal, comprehensive Mountain Goat Habitat Supply Model that will ultimately link mountain goat and habitat monitoring information, forest development planning, and forest management activities. We expect to continue model development & application beyond March 2003 through a large-scale, collaborative, and comprehensive mountain goat habitat modeling effort similar in scope to the Omineca Northern Caribou Project (see http://www.slocan.com/irm/projects/caribou/model/index.html). Our long-range goal is to provide a mountain goat habitat supply model that can be used by the forest industry at a regional and provincial level to plan the provision of mountain goat habitat in the context of sustainable forest management.

Workshop Goals:

Workshop #1 Scoping – overview of mountain goat ecology and management issues; discussion to identify elements of importance to a mountain goat mineral lick habitat supply model

Workshop #2 Netica Model Development – identification of ecological factors and key ecological correlates judged important to mountain goat use of mineral licks; identification of relationships among factors; incorporation of factors and relationships into Netica©

Workshop #3 Model Development, Revisions – review output of preliminary model application (using the area of the lower Ospika drainage, Mackenzie Timber Supply Area)

Workshop #4 Model Testing, Revisions, Recommendations for Future Direction

Overview of Workshop Activities

Three objectives are identified for completion by 31 March 2003:

1) Develop a preliminary, conceptual, Netica-based, Mineral Lick Habitat Supply Model;
2) Conduct a preliminary application of the resulting model to the lower Ospika River drainage
3) Conduct a preliminary test of key node(s) in the resulting model, using empirical data from the lower Ospika River drainage.

The Mineral Lick Habitat Supply Model is an example of conceptual modeling, whereby modeling workshop participants will put forth their knowledge of the ecological factors judged important to mountain goat use of mineral licks and how those factors relate to each other. The concepts that arise from discussions during these workshops will form the basis of an annotated, preliminary Netica-based, Mineral Lick Habitat Supply Model. This model will be used:

- To conduct preliminary assessments of mountain goat management policy options; and
- To assess the interaction and importance of the various factors that influence habitat value.

A preliminary application of the Mineral Lick Habitat Supply Model developed during the workshops will be made to the lower Ospika River drainage. This trial application will:

- Predict the effectiveness of the proposed policy and management alternatives.

Testing of the model is accomplished by linking the model to field results. Using empirical data collected through the Adaptive Management Trial and resource inventories currently underway as components of the Ospika Mountain Goat Project we will be able to:

- Evaluate the accuracy of the model predictions;
- Assess results from the active adaptive management study; and
- Assist in the interpretation of information collected from resource inventories.

Long-range objectives (beyond March 2003) associated with further development, application, and testing of the preliminary model developed through these 4 workshops include using the model to:

- Aid in the selection and testing of criteria and indicators for assessing sustainability;
- Provide a framework for resource inventory of factors considered important in affecting the way goats use mineral licks and trails;
- Provide a framework for monitoring key indicators of sustainability (i.e., model-motivated data collection);
- Provide specific direction for operational management decisions; and
- Provide explicit recommendations for interim mountain goat management policy in the Mackenzie Timber Supply Area.

Products associated with the work enabled by these 4 workshops:
Results and conclusions from this work will be completed by March 31st, 2003 in the following formats:

- An agenda and post-workshop summary for each of the 4 modeling workshops;
- An annotated, preliminary Netica-based Mineral Lick Habitat Supply Model;
- A technical report discussing the results of preliminary application of the model to the Ospika River drainage; and
- A demonstration of the trial application to stakeholders (e.g., slide presentation to the Mountain Goat Management Team, workshop participants, and other stakeholders).

Background Information

Mountain Goat Ecology

Mountain goats (*Oreamnos americanus*), primarily found in rugged terrain at high-elevations, also use mineral licks in forested areas at low-elevations. Mountain goats access low-elevation mineral licks from early spring to late fall (Clare 2001), and previous studies in south-eastern Alaska have documented mountain goat use of forested areas for forage and cover during the winter. Mountain goats are not considered migratory, and females and their natal groups show strong fidelity to their summer and winter ranges. As a result, well-used trail systems develop between high elevation habitat and low-elevation mineral licks, and are traditionally used by goat populations generation after generation (Fox and Smith 1988).

Conflict with Forestry

Due to this apparent dependence on, and fidelity to, forested trail systems, goat populations are potentially threatened by forestry activities. Industrial forest development has the potential to cause disturbance to goats on their winter range, reduce or eliminate access to mineral licks, and create access for hunters to previously un-hunted or vulnerable goat populations.

Mountain Goats in the Lower Ospika River Drainage

The lower Ospika River drainage in the Mackenzie Forest District, north-central British Columbia, supports a population of mountain goats. Timber harvesting in the Ospika valley began in the late 1970's, with the most recent and intense harvesting coming post-1987. In 1988, a mountain goat survey was commissioned by Fletcher Challenge Canada to assess goat populations in the Ospika valley, and to make recommendations concerning future harvest and road construction. This survey raised important management issues about the co-existence of forestry and mountain goats, and also raised alarm about increased hunter access to vulnerable goat populations (Hatler 1988). However, since 1988, no formal study has been done, and there is little information available on Ospika mountain goat populations to make effective and informed management decisions. Forest development plans in the Ospika River valley are encroaching on areas known to be used by mountain goats.

Current Management Guidelines, Policies, and Strategies

Goats and goat habitat are identified as a significant resource in both the Forest Practices Code (FPC) and the Mackenzie Land and Resource Management Plan (LRMP). The Mackenzie LRMP identifies the need to appropriately manage mountain goats and their habitats, but defers all management to policies defined at a regional level. The FPC has sufficient mechanisms to allow for proper management of critical habitats for goats through General Wildlife Measures, Ungulate Winter Range and the Identified Wildlife Management Strategy, but a basic lack of technical information has caused operational management to be essentially non-existent. In general, the available policy mechanisms are so general as to leave specific direction for operational management decisions vague and ineffective.

The Ospika Mountain Goat Project

The Ospika Mountain Goat Project is a 5 year (2002-2007) study funded and administered by Slocan Forest Products Ltd. and the Peace/Williston Fish and Wildlife Compensation Program. The project proposes a concurrent, multi-phase approach to developing and implementing effective forest management strategies that are considerate of mountain goat habitat values. Project components include:

- Adaptive Management Trial
- Habitat Supply Modeling
- Resource Inventory
- Policy Development

Background Information (Continued)

The **Adaptive Management Trial** is a site-specific study to monitor the impact of different forest harvesting strategies on mountain goat use of low-elevation mineral licks and their associated access trails in the lower Ospika drainage. This trial is being conducted by the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP).

Habitat Supply Modeling is a tool used to predict ecological habitat values. Models are useful for strategic planning and decision-making purposes. The models will be tested and refined using data collected during Peace/Williston's Adaptive Management Trial and mountain goat **Resource Inventories** to be conducted throughout the Mackenzie Timber Supply Area. These components of the project are being conducted by Slocan Forest Products – Mackenzie Operations.

Information derived from all project activities will contribute to mountain goat **Policy Development** and review.

A Mountain Goat Management Team (including representatives from industry and government) has been established as an advisory board for the project and for the development and implementation of regional mountain goat management strategies and policies.

The Ospika Mountain Goat Project contacts:

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Goat Mineral Lick Habitat Supply Modeling Workshop

Workshop #1 – Agenda
Monday February 3rd through Wednesday February 5th
Start time 1:00 pm Monday
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Background: see document circulated by Pam.

Objectives of this workshop:

- Summarize the current understanding of the ecological situation based on published scientific results, preliminary results of ongoing studies and expert / professional opinion.
- Scope out the ecological factors that are important and the causal interactions among these factors. Develop a "word model" that describes and summarizes this understanding
- Identify gaps in understanding
- Determine the potential management actions that could be undertaken regarding goat mineral licks, so these "management levers" can be included in the modeling framework.

Agenda:

Introductions and review of the agenda	Rick
Goals for the project – short term (March 2003), longer term	Scott
Overview of the current mountain goat management situation (20 min)	Doug W ?
The mountain goat ecological "story" (30 min)	Doug H/Glen?
Overview of ecological understanding of goat ecology	
Presentation of results and status of current mountain goat projects	
Goats in the Mackenzie TSA (30 min)	Pam
Adaptive management of mineral licks and trails – Ospika (30 min)	Mari / Fraser
Mineral licks (30 min)	Jeremy
Smithers work(30 min)`	Laurence
Scoping: Discussion	Rick
Ecological situation to be modeled	
What habitat types or "sub-types" are of interest	
What interspecies factors are of interest	
What human activities are of interest	
Key indicators - factors to be predicted and tracked by the model	
What factors should be predicted	
What factors should be tracked and reported on	
What management activities should be evaluated	
Scoping: Specifics	
Area over which the model should apply	
Number and type of habitats to be considered	
Potential management activities to be considered as "levers"	

The size of the ecological units of interest – resolution
Time step of the model
Identification of data sources for each factor
Data to be used in model construction
Data to be used in model testing

Modeling
Overview of the Netica modeling approach
e.g. CHASE moose model — Pam
Initial Netica-type chart (word model) of situation (box and arrow model) — Rick

How the model may be used - potential applications.
For example, these types of models can be used to:
Assess areas (map/GIS) and predict the habitat quality
Communicate and test understanding of ecological relationships
Assess relative effects of alternative management scenarios / policies

Next steps:
Preparation required for next workshop
Workshop schedule: Feb. 18, 19, 20; Mar. 5, 6; Mar. 17, 18

Underlying Philosophy Regarding Modeling

All modeling activities contain an inherent philosophy. The philosophy proposed for this project is summarized in the following assumptions:

1. No model is going to be "the true or complete model", therefore it is important to formulate the model explicitly, incorporate empirical data and the recognition of uncertainty into the model, and adapt the model to new empirical information;
2. Alternatively, no finite amount of empirical data or science will form an exact characterization of the ecological situation or relationships, therefore it is important to develop a model that will bridge the gaps in the data and empirical understanding in order to create a more comprehensive, albeit theoretical, understanding of the ecological system;
3. No model, no matter how simple, will be readily implemented at the operations level; therefore it is important to incorporate an interpretive component into the overall project product.
4. An ideal model would be precise, general, and realistic, however one of these elements must be sacrificed if the other two are to be met. This modeling approach is built upon a desire for generality and realism.
5. A model of the type proposed has high value as a tool for comparing alternatives, and testing hypotheses, within the modeling environment.

The modeling approach is designed to:

- Serve as a basis for communication regarding the causal relationships involved in the ecology of mountain goats.
- Consider operational management factors relevant to the area.
- Incorporate data and information from fieldwork.

- Include a framework for analysis and decision-making.
- Consist of an open architecture for the evaluation of results (rather than a "black box" approach).

Workshop Participants:

Invited:	**Confirmed:**
Pam Hengeveld	Yes
Jeremy Ayotte	Yes
Katherine Parker	No
Michael Gillingham	No
Doug Heard	Yes (dependent on field work)
Glen Watts	
Doug Wilson	Yes (Monday)
Dale Seip	Yes
Mari Wood	Yes
Fraser Corbould	Yes
Chris Ritchie	
Bill Arthur	Yes (Monday)
Bernie Banovic	
Doug Ambedian	No
Glenn Goymer	Yes (but not first workshop)
Jim Ladds	No
Patrick Russell	
Murray Both	No
Ross Lennox	Yes
Scott McNay	Yes (Monday)
Laurence Turney – Smithers	Yes

Goat Mineral Lick Habitat Supply Modeling Workshops

Workshop #1 - *Summary*
Monday February 3rd (1 pm) through Wednesday February 5th (3:30 pm), 2003
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Attendance: Rick Ellis (facilitator), Bill Arthur, Dale Seip, Doug Heard, Doug Wilson, Fraser Corbould, Glen Watts, Jeremy Ayotte, Laurence Turney, Mari Wood, Pamela Hengeveld, Ross Lennox, Scott McNay

Introductions / Review of Agenda (Rick)

Project Goals (Scott)

- Long-term: use model as an operational tool, specifically at the Forest Stewardship Plan level
- Short-term (to March 31, 2003): develop a good framework for a goat habitat model, functional in a way that it can be applied in the Ospika
- Scott's "wish list" for this model:
    - Develop something similar in look and feel to CHASE (i.e. same ideas - principles, functionality, application)
    - Less model development time (because a mtn goat model is more of an element-level model than a stand/landscape level model, and we've gained Netica/modeling experience from CHASE development)
    - Maintain excellent collaboration (as with CHASE)

Current Mountain Goat Management Situation

- Yellow-listed (not threatened but of special management concern)
- In draft IWMS
    - Natal areas = critical habitat
    - Mineral licks = important habitat features (visual buffer of 200-400m recommended for WHAs around licks)
- FPC Operational Regulations
    - "significant mineral lick" = a resource feature
    - has mechanisms for proper management (eg UWR, General Wildlife Measures) but lack of explicit direction / technical info = minimal operational management
- Mackenzie LRMP
    - Objective = id high value mtn goat habitat and implement regional management strategies
    - Currently no management strategies exist
    - Slocan has developed a draft interim policy for the Mackenzie TSA

What do managers want from a mtn goat habitat model ?

- Habitat Management
    - UWR scenario (not a general set of requirements)
    - can model predict features (e.g., high and low elevation mineral licks)

    - guidelines for practices when features found
    - trails to low elevation licks and other seasonal movements – landscape features, linkages, disturbance, destruction
    - importance of forested bluffs for winter habitat ?
- Management Levers
    - road access / density, over flight disturbances (local / high density areas), recreational disturbance, storm loss, predation
- Planning
    - clarity re management that should be applied E.g., explicit guidelines, when habitat used, access trails, timing / proximity of industrial activity
    - SFM plans – using model to plan how and what to monitor
    - testing assumptions of model
- Factors
    - hunting access / high female harvest (due to difficulty in identifying sex), timing, use, buffers, visibility and screening, native harvest, bluffs, dry licks

Goat Ecology

- Fine / smaller scale (finer than caribou) - small home ranges
- Tied to cliffs / escape terrain
- Goats > caribou > moose -- goat = most predation risk averse
- Stay close to escape terrain
- Not necessarily tied to high elevations if escape terrain / predator avoidance not an issue at lower elevations
- Licks and access to licks is important (use involves predation risk)
- Live in huge range of snow depths, winter where forest canopy intercepts snow (forage availability), snow = predator barrier
- Natal areas are important - steep terrain, predation cover (trees?)
- Hunting – small populations – viability?
- Aircraft disturbance – whole population impacted
- Diet – eat anything, not restricted by food requirements
- Effective anti-predator strategists – but same issue as caribou (goats are an alternative prey)
- High fidelity to trails / licks, over generations
- Variations in how populations use habitat?

Current Mountain Goat Projects

The Ospika Adaptive Management Trial

Peace/Williston Fish & Wildlife Compensation Program (Mari / Fraser)

- Trail buffer 100 m each side
- Trails
    - 1 main or fingers, from alpine to licks
    - not linear as crow flies – to bluffs / breaks (~ up to 500 m between bluffs) - staging areas on route
    - check out before using trail (spend time watching the trail before leaving the lick)
    - day and night use of licks / trails
    - trails = goat trails that other species also use
    - move fast on trails
    - follow terrain – ridges – escape
    - no ecological characteristics of trail importance

- high affinity to trails

Mackenzie TSA Goats
Slocan (Pam)

- 4 distinct peaks in trail use on 4 dates (in Aug, Sep, Oct)
- used in early spring – April
- segregated use by sex ? open question
- seasonal use / peaks
- 70% day use, 30% night use, different patterns on different trails / licks
- dispersed licking important

Physiological importance of wet & dry licks to ungulates
UNBC MSc candidate (Jeremy)

- working in Tuchodi Lakes area, Muskwa-Kechika, northern Rockies
- theories on importance of licks: 1) replenish mineral deficiencies due to diet, 2) as buffers (ingest carbonates and clays to balance pH)
- preferred licking sites within the licks
- weather had a big effect on dry lick use
- behaviours monitored at licks were bedded, standing, licking
- active infrared cameras were established at dry licks
- 3 dry licks, 3 wet licks monitored
- goats displace sheep at dry licks

Smithers Goats
Ardea Consulting (Laurence)

- Nadina Mtn (SW of Houston)
- looking at forested habitat use
- goats found to be at the sites for 1-3 days (based on camera data)
- have taken the inventory approach rather than the modeling approach to identify goat habitat
- used Netica for a lot of habitat supply modeling for other species (not goats)
- have some goat management strategies in place at Foxy Creek site
- no movements during poor weather conditions

Scoping: discussion

- Do we know all the licks in the TSA? Most major ones (?) (think that most large low elevation licks of ~3-4 ha have been identified in key valleys)
- What size can we identify on airphotos, maps, etc – staging areas? No – probably too small.
- What size do we want to look at for licks? Suggest 2-3 ha, 5 ha

end of Day 1

Scoping

Objective

- Build a framework to model the whole "goat story", then we can focus on licks/trails as a component of the more comprehensive model.

Assumptions

- food may be limiting, but trade-off to avoid predation. Predator avoidance is more important than food
- No displacement of goats at the licks (by other species)

Habitats of interest

- Natal areas / escape terrain
- No / low snow
    - Licks
    - Trails / escape "bluffs" staging areas
        - Straight lines, high affinity, traditional use over time
    - Summer alpine + high elevation licks
- Deeper snow (winter)
    - Winter alpine – windswept
        - Avalanche risk
    - Subalpine / snow and escape terrain
        - Subalpine, steep, low value timber
        - Avalanche risk
- Bluffs (in forested areas)– used year-round e.g., canyons, Nadina moutain
        - Avalanche risk

Interspecies factors of interest

- Natal areas
    - Eagles, wolverines, wolves, bears
- Licks
    - Bears, wolves (bears higher risk due to greater chance of encounter)
- Trails
    - Bears, wolves, cougars
- Alpine summer
    - Bears, wolverine
- Winter alpine / subalpine
    - Wolverine (bears asleep, wolves not in area)

Human activities of interest

- Natal areas
    - Harrassment by air (causing direct mortality) – distance, # of flights. Critical areas and critical timing only. Could deal with this via no fly window ~ May 21-June 21.
- Licks and trails (low elevation)
    - Aerial harassment – response not considered to cause direct mortality (flee into forest)
    - Goat hunting at bluffs, licks – poaching, subsistence, regulated
    - Roads – contribute to increased hunter access, thus increased goat harvest
    - Timber harvest
    - Oil and gas, mineral exploration – over flights and road construction
    - Recreation - ATVs

- Alpine summer
    - Goat hunting (regulated)
    - Roads and cutblock access / screening
    - Recreation - ATVs
- Winter alpine / subalpine
    - snowmobiling

Disease transfer – domestic sheep, goats, llamas

Management Levers

- Flight rules
    - Distance from (vert and horiz), # of flights. No fly zones / times
- Recreation
    - Hiking, skiing, wildlife viewing distances
- Hunting regulations
    - LEH, small areas
- Screen / visual management / sight distances
- Trail buffers - ~100 m each side
- Cutblocks
- Road proximity to licks – adjacent, crossing trails
- Timing of road building
- Timing of logging
- Timing of mineral exploration / oil and gas
- Traffic management on roads – traffic density, harassment?
- Road deactivation (complete reclamation)
- Alpine/subalpine – no roads, no harvestable timber

Limiting factors for goats

- Accidents
- Avalanches
- Predation
- Starvation
- Hunting (roads – regulated hunting primarily, poaching, subsistence)
- Harrassment
    - Short term – over flights on natal and steep/escape terrain, researchers
    - Longer term - ? snowmobiles, trucks, recreational (hiking, skiing)?
- Roads / cutblocks
    - Remove cover on trails – impact? Re-growth density (low visibility in 15-20 year old regen)? Trails all in mature open forest?
    - Access to hunters
    - Access to predators – bears use roads (travel and roadside feeding) and cutblocks (feed in early seral, 0-20 yr old cutblocks). Duplicate moose-wolf model and include bears to get predation risk model for goats at low-elevations.

Habitat Characteristics

- Low-elevation forested licks
    - Within 300 m of a creek / gully
    - Unstable terrain

- Break in topography
- Lacustrine / fine soils (surficial / soils map)
- Forest Inventory – identified clay banks, environmentally sensitive areas
- Within 5 km of alpine >>> include this as a general rule, but do not apply it in the study area (5 km is too great a distance – everything in the study area is within 5km of alpine)

- Trails
  - User defined?
  - Straight as possible – topographic influence
  - Start at escape terrain in alpine
  - 500 m / 1000 m bluff to bluff
  - forest is not as important as bluffs on either end
  - "bluffs" = creek draw break, ridges
  - shortest distance between bluffs
  - 1 ha – ¼ ha
  - same as subalpine escape terrain
  - 20 m height difference
  - start to end point connection
- Alpine
  - Summer habitat
    - Not limiting
    - 45-60 degrees
    - all aspects
    - 2-3 ha
    - 1 km movement from escape terrain
  - Winter habitat
    - Steep 45-60 degrees
    - Feed on windswept ridges adjacent
    - South aspect
    - Roughness – no avalanches
    - Adjacent to but not avalanche track (Forest Cover data, TEM better)
    - Not glacier (TRIM data)
- Natal Areas
  - South facing
  - Steeper (50-60 degrees)
  - 1 ha +
  - roughness
    - Laurence's script: looked at slope change of 20-30 degrees within 100 m of each 25 m grid.
    - For Ospika – we have mainly 1:10 M contours, 1:20 M for more isolated, northerly areas
  - Geology – volcanics, limestone
  - Biophysical
  - Within 500 m from edge of subalpine winter range

Study area (Short term – to March 31 2003)
- Lower Ospika (good animal data)
- Upper Ospika
- Pesika / Akie (good base data)

Netica model development

- Used the habitat types, factors, and management levers identified above to construct 5 Netica model frameworks:
  - Alpine winter escape terrain
  - Subalpine / forested winter escape terrain
  - Natal area
  - Low-elevation mineral licks
  - Trails

End of Day 2

Netica model development

- Filled in the CPTs for all 5 Netica models
- Defined and labeled the states for each node in the models
- Discussed alternatives for modeling predation risk
  - Include bears in a modified CHASE moose-wolf abundance model
  - Model predation risk as a function of trail/lick proximity to early seral habitats (favourable habitat for alternative prey & predators)
- Result = 5 functional goat habitat models

End of Day 3

ACTION ITEMS

Ross	Soils map, geology map, interp terrain - availability?
Laurence	Roughness GIS script
Scott / Pam	Predation Model – set up GIS script for proximity to early seral (or expand CHASE moose-wolf model to include bears)
Pam	Document the model, Netica - reorganize state orders (ensure states = explicit names and defined measurables), rename nodes (CHASE codes)
Pam / Scott	Prep base data – 3 areas (same as CHASE data)
Pam	Trails map – after running forested, alpine, licks models

NEXT MEETING

Workshop #2 scheduled for February 18 – 20, Prince George.

Adjourned

Goat Mineral Lick Habitat Supply Modeling Workshop

Workshop #2 – Agenda
Tuesday February 18 through Thursday February 20
Start time 9:00 am, Tuesday
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Objectives of workshop:

- Review the conceptual basis, relevant factors and relationships included in the draft Netica models.
- Review and revise the draft Netica models – all factors, states and CPT tables
- Identify gaps in understanding
- Develop the models to the point where they can be run on the Lower Ospika study area.

Note: at the request of some of the key people on the team, the agenda is structured to provide an opportunity to review and comment on the work-to-date on the models in a focused way on the morning of Feb. 18. Hopefully most of the team will be able to continue working with us on the detailed work of further developing the models for the rest of the workshop.

Agenda:

Feb. 18, 9:00 – 12:00

Review of previous workshop activities and progress on the development of the 5 Goat models. Each model will be presented. The focus will be on reviewing the general structure of each model to ensure all team members have an opportunity to review and comment on model development.

Goat Models:

1. Alpine Winter Escape Cover
2. Forested Winter Escape Cover
3. Natal Areas
4. Trails to Low Elevation Mineral Licks
5. Low Elevation Mineral Licks

Feb. 18, 1:00 – 4:30 and Feb. 19, 20

Detailed review of each of the 5 Netica models under development to apply our best understanding of the ecological situation to the models. The state values for each factor in each model will be reviewed and revised as necessary. The CPT tables will be reviewed and revised to reflect the current understanding of the causal relationships among the factors.

Review of how the 5 models may be used:

For example, these types of models can be used to:

Assess areas (map/GIS) and predict the habitat quality
Communicate and test understanding of ecological relationships
Assess relative effects of alternative management scenarios / policies

Next steps:

Preparation required for next workshop – March 5 - 6

Goat Mineral Lick Habitat Supply Modeling Workshops

Workshop #2 - *Summary*
Tuesday February 18th (9 am) through Thursday February 20th (12 pm), 2003
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Attendance Working session - Rick Ellis (facilitator), Dale Seip, Doug Wilson, Fraser Corbould, Mari Wood, Pamela Hengeveld
Review session – Bill Arthur (in addition to the above)

Workshop Goals

- Review the conceptual basis, relevant factors and relationships included in the draft Netica models – revise the models and CPT tables.
- Develop a desired set of products from the model runs
- Develop a plan for next steps and tasks
- Plan the next workshop

Refining the Models - Summary of Discussion

Escape Habitat Model

- Discussed the need for an alpine summer habitat model (natal areas are tied to summer habitat, hunting pressure, potential for mineral/oil/gas industry impacts)
- Noted that important feature in alpine summer, natal areas, alpine winter, and forested escape habitats = steep, rough terrain. Thus, a single model can represent all four habitat/range types. Each type can be distinguished as a sub-set of the general model by simple addition of 1 or 2 parameters unique to each (e.g., restricted to south aspects in winter)
- Preferred escape habitat is defined as steep, rough slopes that are non-forested and not a glacier.
- Escape habitat value is reduced by:
    a) Increased predation risk due to the proximity of cutblocks (identified by evaluating the amount of high value predator habitat, i.e, mesic/hygric cutblocks <40yrs old, within a 2km radius)
    b) Increased local goat harvest due to the proximity of roads and cutblocks (within 500m, 500-2000m, and >2000m).
        - Decided not to distinguish between types of hunting. Guided harvest is not related to road proximity (so it's irrelevant here); regulated & unregulated harvest both have potential for increased impact at a site as road access develops, however harvest management would require local hunting restrictions (which gov't wants to avoid).
        - Agreed that a baseline level of hunting at a site will increase as road access increases. It is the increase that we are concerned about (assumed >3% increase = unsustainable). Overall, easiest way to manage hunting pressure at a site is to manage road access to the site.

- Providing a visual screen / buffer around the site is not thought to be effective (i.e., if a site is known and there is access to it, then goats are vulnerable to harvest), but screens/buffers can be evaluated in scenario runs, rather than as a node in the model.
- Used 2000m as a cut-off to be consistent with IWMS / WHA recommendations

c) Aerial disturbance (frequent fixed-wing and heli flights in close proximity to goats on escape terrain have the potential to cause direct mortality i.e., goat falls or jumps)
   - Aerial disturbance is included in the model, but there is no input data for this, and it is not a dynamic factor (thus trivial in a spatial-dynamic model). It may be retained in the model to identify over-flights as an issue of concern, but it might best be considered as a "rule" (i.e., don't fly within 500 m of goat escape habitat) rather than a management lever.
   - Fixed-wing and heli impacts not differentiated because flight proximity and duration levers will capture the difference between the two.

d) Ground-based disturbance

Trails Habitat Model

- Important to have all factors considered in the Adaptive Management Trial included in the models
- Hypothesis: Goat behaviour will change if trail canopy cover is removed. Expect that goats will show preference for trails in non-seral habitats, so added a node to characterize trail preference based on stand age (visibility through the forest is presumed to be reduced in stands aged 15-80 yrs).
- Trails = a user-defined input. Effective width of the trail was identified as 50m (25m each side of the trail).
- Trail habitat value is reduced by:
  a) Increased predation risk (identified by evaluating the amount of high value predator habitat, i.e, mesic/hygric cutblocks <40yrs old, within a 2km radius)
  b) Ground-based disturbance
- Discussed whether the trail itself might be attractive to predators (irrespective of proximity to early seral cutblocks) – can add a predator control management lever to deal with this

Low-Elevation Mineral Licks Habitat Model

- Lick habitat preference is defined by unstable (failed) slopes that are claybanks and/or have fine/lacustrine soils
- Lick habitat value is reduced by:
  a) Increased predation risk (identified by evaluating the amount of high value predator habitat, i.e, mesic/hygric cutblocks <40yrs old, within a 2km radius)
  b) Increased local goat harvest due to the proximity of roads and cutblocks (within 500m, 500-2000m, and >2000m).
     - Decided not to distinguish between types of hunting. Guided harvest is not related to road proximity (so it's irrelevant here); regulated & unregulated harvest both have potential for increased impact at a site as road access develops, however harvest management would require local hunting restrictions (which gov't wants to avoid).
     - Agreed that a baseline level of hunting at a site will increase as road access increases. It is the increase that we are concerned about (assumed >3%

increase = unsustainable). Overall, easiest way to manage hunting pressure at a site is to manage road access to the site.
    - Providing a visual screen / buffer around the site is not thought to be effective (i.e., if a site is known and there is access to it, then goats are vulnerable to harvest), but screens/buffers can be evaluated in scenario runs, rather than as a node in the model.
    - Used 2000m as a cut-off to be consistent with IWMS / WHA recommendations
  c) Ground-based disturbance sub-model.

Disturbance Impact sub-model

- Ground disturbance is a potential factor in all habitat/range types, so a disturbance sub-model was developed as an input to the lick, trail, and escape models.
- The disturbance model was expanded to include human activity separate from roads and machines, and structured such that the 3 disturbance types could be additive.
- Includes ground-based disturbance caused by:
  a) Traffic on roads that cross or are adjacent to trails and licks (impact determined by a combination of seasonal timing, road traffic frequency, and road proximity)
  b) Noise from machines working on cutblocks in close proximity to the trails and licks (impact determined by a combination of seasonal timing and proximity to active blocks)
  c) Human presence on or near the trails and licks (impact determined by a combination of seasonal timing, days between visits, and proximity). This includes cruising, layout, and silviculture crews (ie., crews associated with planned industrial activity such as timber harvest).

General Overview of the Modeling Process

While our work is currently focused on developing a simple, preliminary habitat supply model (steps 1and 1b below), it's helpful to have some idea of what the next steps (1c-4 below) might be (beyond March 31, 2003)

1. Initial modeling (1 time step, e.g., current situation)
   a) Develop model(s), focus on goat habitat
   b) Run the model(s) to get output products (maps, etc) that demonstrate the current situation for goat habitat supply
   c) Test the models, e.g.:
      - Was the model successful in identifying habitats that we wanted it to predict? May conduct inventories to ground truth the results.
      - Do the preference nodes accurately represent habitat selection by mountain goats? May conduct statistical analyses using radio-telemetry data to assess model output.
   d) Revise the models
2. Model changes in habitat supply over time (multiple time-steps)
   a) Run SELES (landscape event simulator software) to assess landscape changes over time
   b) Run the model(s) to get outputs for multiple time steps
3. Run various scenarios to get a sense of limiting habitats and alternate management plans

4. Integrate population information with the habitat supply model
    a) Run RAMAS and/or SELES software to develop a spatial population model

End of Days 1& 2

Products to be produced by the project (for the next workshop):

Basic:

- Map of study area (L. Ospika) including a 2 km buffer around the study area, showing current roads and cutblocks
- Map of areas identified as irregular by roughness script (to check out the script)

Predation:

- Map of study area showing levels of predation risk

Hunting:

- Map of study area showing levels of increase in hunting harvest of goats

Disturbance:

- Map of areas of Industrial Activity (Cutblocks and Mineral Activities) showing levels of disturbance resulting from the activity
- Map of road traffic disturbance area showing levels of road traffic disturbance (proximity only since no frequency data is available)
- Map of total ground disturbance showing levels of ground disturbance

Trails:

- Netica model
- Map of trails (50 m total width) by preference class (preference node results)
- Table of the total area of trails and the area in each preference class
- Map of trails (50 m total width) by habitat value class (habitat value node results)
- Table of the total area of trails and the area in each habitat value class

Low Elevation Mineral Licks:

- Netica model
- Map of mineral lick by preference class (preference node results)
- Table of the total area of mineral lick and the area in each preference class
- Map of mineral lick by habitat value class (habitat value node results)
- Table of the total area of mineral lick and the area in each habitat value class

Escape:

- Netica model
- Map of escape by preference class (preference node results)
- Table of the total area of escape and the area in each preference class
- Map of escape by habitat value class (habitat value node results)
- Table of the total area of escape and the area in each habitat value class

Model Run Requirements (in addition to base data):

Disturbance:

- Proximity of roads – road traffic
- Proximity of current cutblocks and mineral activity sites (if available)
- Set management levers as follows:

- Human – off (Nov. – Apr.)
- Industrial Activity – off (Nov. – Apr.)
- Roads – on (May – Oct.); Freq = 1-2

Trails:

- Predation Risk
- Map of Trails
- Ground Disturbance

Mineral Licks:

- Predation Risk
- Ground Disturbance
- Hunting increase – proximity of roads
- Soil texture / Terrain stability grids

Escape:

- Roughness
- Table of nonforested
- Hunting Increase – proximity of roads
- Aerial disturbance – off (proximity GT 2000m)
- Predation Risk
- Ground disturbance

GIS Scripts Required:

A. Road Disturbance - Proximity of Roads:
Centerline of trail to centerline of road
Categories: 0-25m; 25-400m; (400+m)

B. Increased Goat Harvest – Proximity of Roads or Cutblocks:
Categories: 0-500m; 500-2000m; (2000+m)

C. Machine Disturbance - Proximity of Cutblocks harvested in the current year:
Categories: 0-400m; 400-1000m; (1000+m)
Note: when available, add location of Mining activities (camps, well heads, exploration) and treat these activities the same way cutblocks are treated in the model

D. Roughness (Laurence script or create new script)

E. Predation Risk: Proximity of Predator Habitat
Predator Habitat: Less than 40yrs and Mesic or Hygric ecosystems (BEC units)
Categories: Determine the area of Predator Habitat within a 2 km buffer
If 30% of total area is Predator Habitat than Risk Rating is High
If 10 - 30% of total area is Predator Habitat than Risk Rating is Moderate
If less than 10% of total area is Predator Habitat than Risk Rating is Low

Review Session

- Updated participants on status of the models
- Reviewed product list and task list

End of Day 3

TASK LIST

Task:		Done by:	Who:
1.	Prepare draft notes from the workshop	Feb. 24	Pam
2.	Prepare workshop report	Feb. 21	Rick
3.	Prepare rationale for aerial disturbance model component	Feb. 26	Mari
4.	Prepare rationale for ground disturbance model component	Feb. 26	Mari
5.	Prepare rationale for predation model component	Feb. 26	Mari
6.	Prepare rationale for Hunting increase model component	Feb. 26	Mari
7.	Prepare model documentation	Mar. 7	Rick
8.	Revise models (model custodian)	Feb. 20	Pam
9.	GIS Scripts and runs – Road Disturbance	Mar. 3 ?	Jon
10.	GIS Scripts and runs – Increased Goat Harvest	Mar. 3 ?	Jon
11.	GIS Scripts and runs – Machine Disturbance	Mar. 3 ?	Jon
12.	GIS Scripts and runs – Roughness	Mar. 3 ?	Jon
13.	GIS Scripts and runs – Predation risk	Mar. 3 ?	Jon
14.	Documentation of GIS scripts	Mar. 3 ?	Jon
15.	Prepare table of values to be included in Non-forested List of ITGs that should be considered non forested in Netica escape model	Feb. 25 ?	Pam
16.	Prepare table of values to be considered predator habitat List of BEC units to be classed as mesic / hygric for predation risk GIS	Feb. 26	Pam / Randy
17.	Prepare study area boundary map – including buffer (roads and blocks)	Feb. 28	Karin
18.	Prepare base data layers for model runs, including soils and terrain	Feb. 28	Karin
19.	Run Netica models	Mar. 7	Pam
20.	Prepare products (see list)	Mar. 14	Karin / Pam
21.			
22.			

NEXT MEETING

Workshop #3 scheduled for Mar. 17, 18 - Purden Rm. @ 9:00.
Project Review / Presentation: Mar. 31 – Purden Rm @ 9:00

Adjourned

Goat Mineral Lick Habitat Supply Modeling Workshop

Workshop #3 – Agenda
Monday Mar. 17 through Tuesday Mar. 18, 2003
Start time 9:00 am, Monday
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Objectives of workshop:

- Review progress on model development (see task list from workshop 2 report)
- Review preliminary model results (to be presented at workshop)
- Review and revise the current Netica models, as needed
- Review draft model documentation (to be presented at workshop)
- Plan next steps

Agenda:

Mar. 17, 9:00 – 4:30

Review of progress on model development. The task list from workshop report 2 will be used as a basis for reviewing activities and reporting progress.
Review of preliminary model results

Mar. 18, 8:30 – 3:00

Review and revision of Netica model structure and CPT tables (see attached note from Mari)
Review of model documentation
Next steps:
Preparation for next workshop – Mar. 31

Goat Mineral Lick Habitat Supply Modeling Workshop

Workshop #3 – Summary
Monday March 17th (9am) through Tuesday March 18th (10am), 2003
Purden Room, 4th Floor, 1011 Fourth Avenue, Prince George

Workshop Activities:

- Review the status of progress on running the models
- Review and revise the models based on concerns raised regarding CPT consistency between models, and the need to split the Escape model into summer and winter
- Determine the management application of the model
- Develop a plan for next steps, tasks, model runs, and workshops

Participants: **Working session:** Fraser C., Mari W., Pam H., Ross L., Glen W., Rick E.
Review session: Bill A.

Next Workshop: May 7, 8 - Purden Rm. @ 9:00

Workshop Results: Project Status

Study Area Map:

- The current study area was chosen based on the availability of biophysical data – it is smaller than the area that will likely be covered by the radio telemetry locations of goats, however it is satisfactory for model development.

Roads:

- Use roads (2002) data set. Ross to provide road info and coding of whether the road is active in summer, winter or both.
- Revise model to indicate the states of roads are: 0-50 m, and 50–400 (resolution limitations dictate this scale)

Cu-tblocks:

- Use cut-block (2002) data set. Ross to provide cut-block info and coding of the year the block will be logged and whether it is summer or winter.

Mineral Activity:

- No input data – no known activity in the area.
- Check with SRM for mineral tenure, road and activity data layer.

Ground disturbance:

- Runs based on cut-blocks and roads

- Eliminate timing factor from sub-model. Use coding of roads and cut-blocks to determine season of activity

Aerial Disturbance:

- Prepare as a sub-model to match documentation

Predation Risk:

- Currently running on stand age only
- Need biophysical data from Atticus (data format problem)

Trails:

- Four known trails are plotted and used in the model runs
- There is one additional trail that will be included (Pam has data from Bill)

Low Elevation Mineral Licks:

- Not run
- Need biophysical data from Atticus (data format problem)
- hunting node – change node name to "local unregulated harvest"

Summer Escape (old escape):

- Not run
- Need roughness script – not a technical problem; simply time required
- Need table of forested / non forested ITGs

Winter Escape (new model):

- Add aspect and avalanche components (as developed in previous versions of winter model)
- Need roughness script – not a technical problem; simply time required
- Delete local harvest – no regulated harvest at this time of year and unregulated harvest is not a significant factor in winter
- Delete predation risk – main predators are wolverine (wolves have more difficulty moving to escape areas and are less successful hunting there in winter)
- Disturbance – eliminate timing factor from ground disturbance sub-model. Use coding of roads and cutblocks to determine season of activity

Model Products required:

- Confirmed list developed at previous workshop

Assessment of Progress:
Deliverables for FII contract done
One road-block to progress – biophysical information in useful format – Atticus

Task List:

Task:	Done by:	Who:
23. Prepare workshop report	Mar. 20	Rick / Pam
24. Revise models (model custodian)	Done	Pam
25. Add 5th trail to trail data layer	Mar. 21	Pam
26. Prepare table of values to be included in Non-forested List of ITGs that should be considered non forested in escape	Mar. 31	Pam
27. Edit Ch 3 of model documentation to reflect current models	Mar. 26	Mari
28. Edit Ch 2 – Management Application	Mar. 26	Rick
29. Review Ch 2	Mar. 26	Ross
30. Delete Ch 4 from documentation	Mar. 20	Pam
31. Edit Ch 5 - Interpretations	Mar. 26	Rick
32. Prepare users guide	Mar. 26	Pam
33. Provide data layer of roads (2002 + 5 years) coded by season	Mar. 21	Ross
34. Prepare data layer of cut-blocks (2002 + 5 years) coded by season	Mar. 21	Ross
35. GIS – Roughness	Mar. 31	Pam
36. Prepare and deliver presentation on project in Mackenzie - Slocan, Abitibi, MoF, Mtn Goat Mgmt and Modeling groups	Mar. 31	Pam
37. "Manage" the delivery of useful Biophysical information	Apr. 7	Pam / Scott
38. Prepare table of values to be considered predator habitat List of BEC units to be classed as mesic / hygric for predation risk	Apr. 10	Pam
39. Prepare FII proposal	Apr. 3	Pam
40. Develop Mineral activity data layer (Ramona Blackwell – SRM)	Apr. 15	Pam
41. Run Netica models	Apr. 30	Pam
42. Prepare products (see list in workshop report #2)	May 6	Pam / Karin
43. Next workshop to review model results	May 7, 8	Pam / Rick
44. Mountain Goat Management Team meeting	May 9	Pam / Mari

APPENDIX B. POSTERS DEPICTING RESULTS OF TRIAL APPLICATION OF THE MODEL TO THE OSPIKA RIVER DRAINAGE

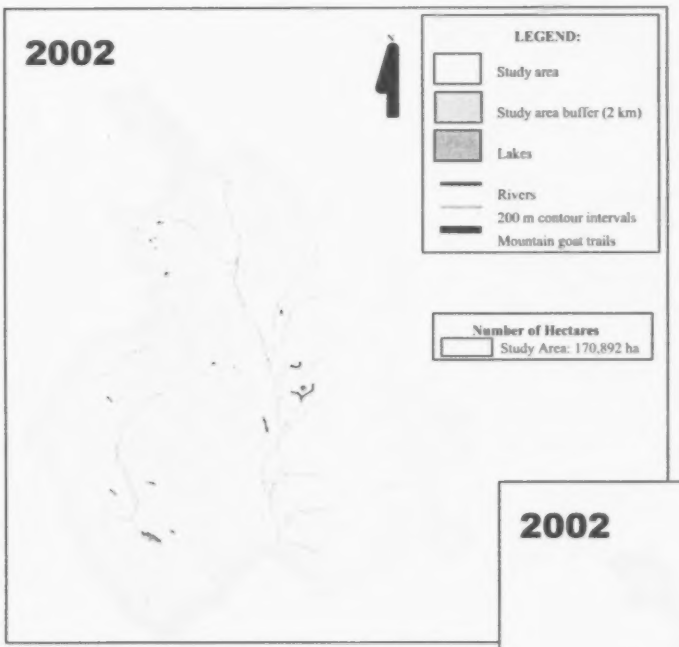
THE OSPIKA MOUNTAIN GOAT PROJECT

Adaptive Management & Habitat Supply Modeling

Study Area

The lower Ospika River drainage (south of Mt Lady Laurier – Chowika Creek) was identified as our area of interest; the study area was subsequently reduced due to availability of the required input data.

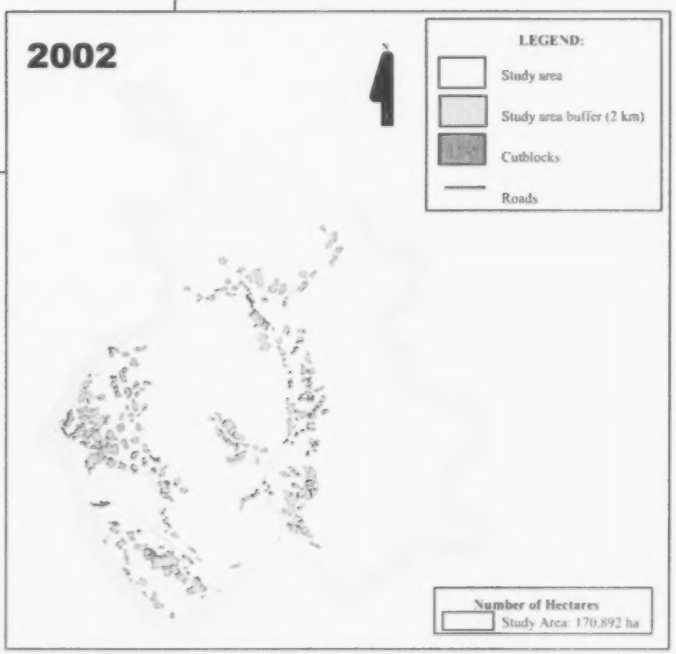
A 2 km buffer around the study area was required for proximity data analyses.



Input data:

The mountain goat trails presented here access AMT study licks 17, 28, 30, and 40. The trails were spatially documented using a handheld GPS unit (PWFWCP and Slocan; 1998-2001).

They are shown as polylines with a 50 m buffer (effective trail width is 100 m).



Input data:

Cutblocks include all blocks (current, approved, and new 2002) identified in Slocan's Development Plan (data from July 05 2002).

Roads include all road types (current, approved, and proposed) identified in Slocan's road shapefile (data from June 10 2001).

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THE OSPIKA MOUNTAIN GOAT PROJECT

Adaptive Management & Habitat Supply Modeling

Proximity of Road Disturbance

The impact of road traffic on mountain goats using low elevation mineral licks and trails is a function of the Timing and Frequency of vehicle traffic, and Proximity of the road to the lick access trails.

2002

LEGEND:

- Low: Greater than 400 m from a road
- Moderate: 50 m – 400 m from a road
- High: Less than 50 m from a road
- Study Area buffer (2 km)
- Rivers

Number of Hectares per Disturbance Category

Low:	137,539 ha
Moderate:	26,275 ha
High:	7,078 ha

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THE OSPIKA MOUNTAIN GOAT PROJECT

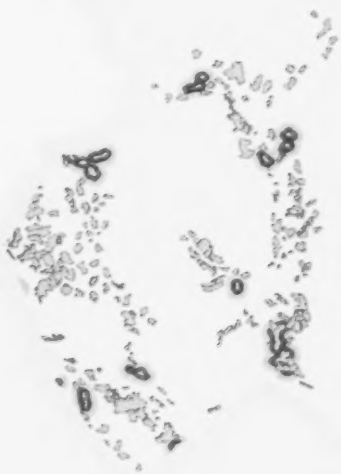
Adaptive Management & Habitat Supply Modeling

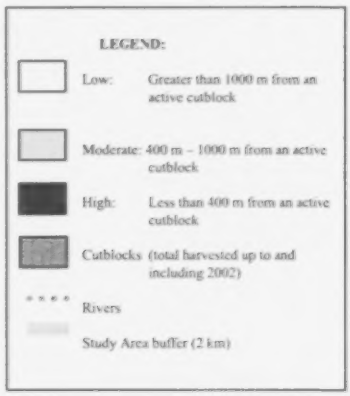
Proximity of Industrial (Noise) Disturbance

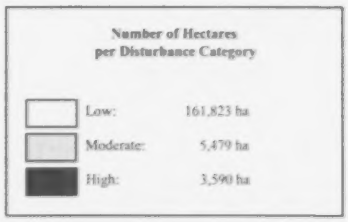
The impact of industrial activity on mountain goats using low elevation mineral licks and trails is a function of the Timing and Proximity of the disturbance to the licks and trails. Industrial activity (noise from machinery) will be present in the year when cutblock(s) are being harvested.

We defined current year blocks as those identified by Slocan as having block status 'New 2002'. All other block status categories were grouped and considered to have been logged prior to 2002.

2002




LEGEND:
Low: Greater than 1000 m from an active cutblock
Moderate: 400 m – 1000 m from an active cutblock
High: Less than 400 m from an active cutblock
Cutblocks (total harvested up to and including 2002)
Rivers
Study Area buffer (2 km)



Input data:
Forest cover (grid)
Cutblocks (grid)
Study area mask (grid)

Current year blocks = those identified as Block Status 'New 2002' (Slocan Data).

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THE OSPIKA MOUNTAIN GOAT PROJECT

Adaptive Management & Habitat Supply Modeling

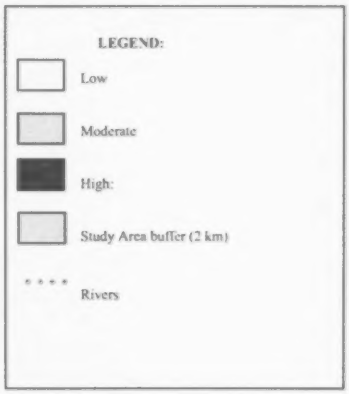
Total Ground Disturbance

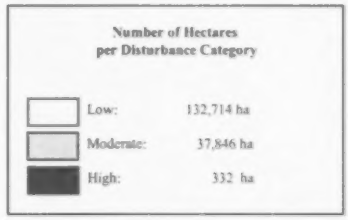
A ground disturbance sub-model was developed as an input to the mineral lick, lic access trail, and escape habitat models. This sub-model considers impacts from:

- **Industrial activity (noise from machinery in close proximity to the licks and trails)**
- **Road traffic (on roads crossing or adjacent to the lick access trails)**
- **Human activity (people traveling on or near the licks and trails)**

Map depicts Netica output for expected values of total ground disturbance.

2002





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Adaptive Management & Habitat Supply Modeling

Predation Risk to Mountain Goats

We hypothesized that predation risk is correlated to the proportion of high value predator habitat present in the surroundings. Proximity to moist, early seral habitats may increase predation risk for mountain goats because it encourages increased numbers of a variety of potential mountain goat predators (bears, wolves, lynx, cougars). We defined moist, early seral habitats to include:

- **Stand age: <40yrs**
- **Moisture regime: Mesic – hygric (no current input data)**

2002

LEGEND:

Low:	< 10 % of area in 2 km radial buffer is early seral habitat
Moderate:	10 - 30 % of area in 2 km radial buffer is early seral habitat
High:	>30 % of area in 2 km radial buffer is early seral habitat
	Rivers
	Study Area buffer (2 km)

Number of Hectares per Risk Category

Low:	97,468 ha
Moderate:	53,472 ha
High:	19,952 ha

Input data:
Forest cover (grid)
Cutblocks (grid)
Study area mask (grid)

FC stand ages were updated to 2002.

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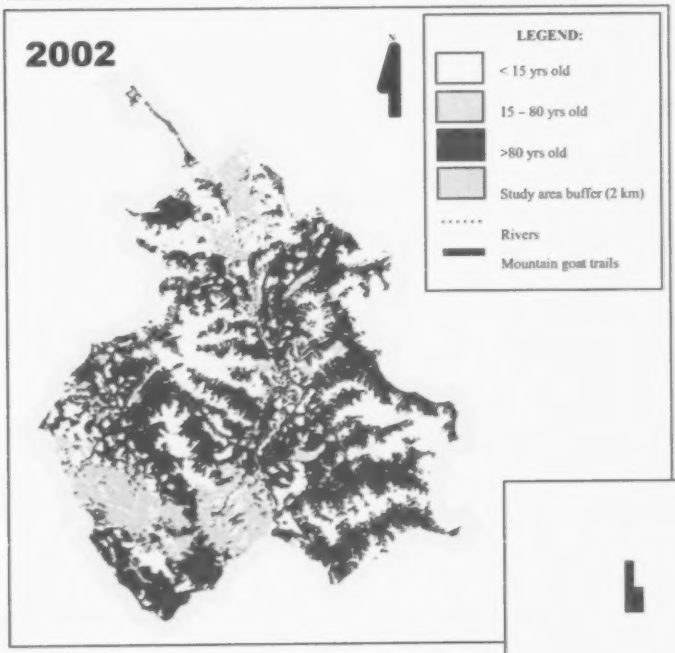
THE OSPIKA MOUNTAIN GOAT PROJECT

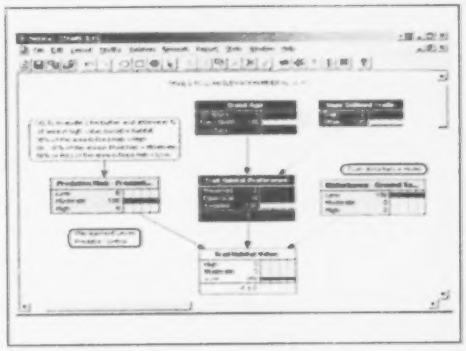
Adaptive Management & Habitat Supply Modeling

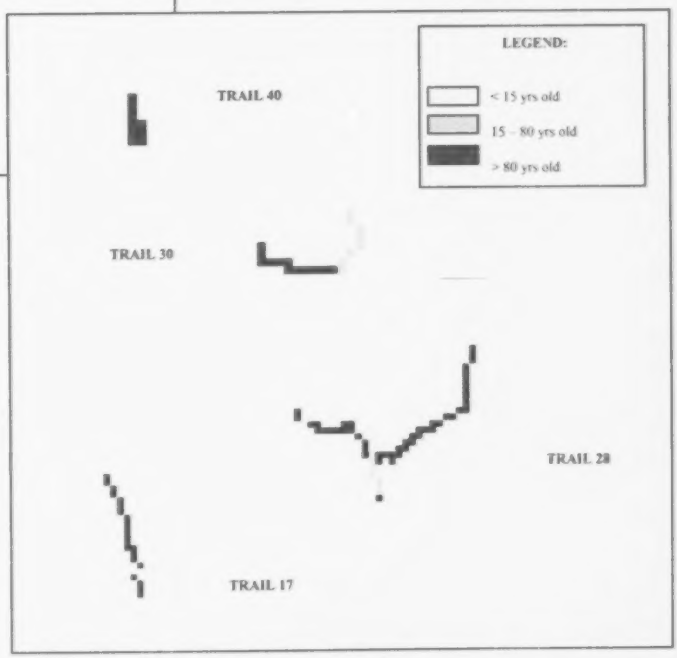
Trail Habitat Preference

The mountain goat trails presented here access Adaptive Management Trial study licks 17, 28, 30, and 40. The trails were spatially documented using a handheld GPS unit (PWFWCP and Slocan; 1998-2001). They were drawn with a 50 m buffer, producing an effective trail width of 100 m.

Trail preference is thought to be influenced by stand age.







Total area by stand age class

Stand Age	Hectares	Percent (%)
< 15 yrs old	5	4.5
15 – 80 yrs old	15	13.7
> 80 yrs old	90	81.8
	110 ha	**100 %**

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THE OSPIKA MOUNTAIN GOAT PROJECT

Adaptive Management & Habitat Supply Modeling

Trail Habitat Value

The mountain goat trails presented here access Adaptive Management Trial study licks 17, 28, 30, and 40. The value of the trails is impacted by the risk of predation and the extent of ground disturbance in proximity to the trails (based on the proximity of roads and active cutblocks).

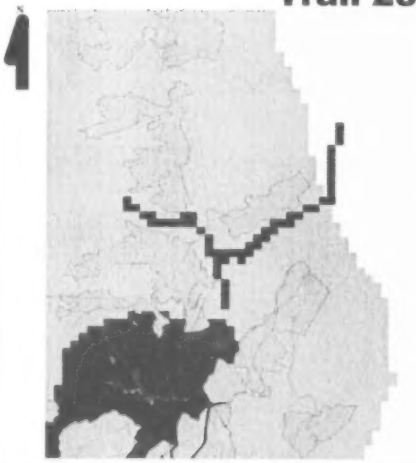
Maps depicts Netica output of expected habitat values for each of the 4 study licks, with predation risk, roads, and cutblocks identified for reference.

Trail 17

LEGEND:

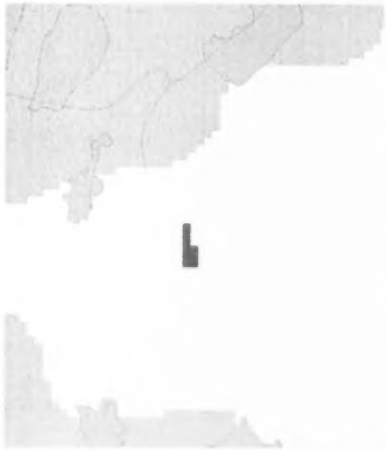
- Preferred trail habitat
- Equivocal trail habitat
- Avoided trail habitat
- Low predation risk
- Moderate predation risk
- High predation risk
- Cutblocks (total)
- Roads

Trail 28



Trail 30

Trail 40



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March 2003

APPENDIX C. PRESENTATION TO STAKEHOLDERS: GOAT HSM AS A FOREST MANAGEMENT AND PLANNING TOOL

Mountain Goat Habitat Supply Modeling
Slide Presentation / Progress Report

Monday March 31st, 10 am
Wood Products Boardroom, Slocan Woodlands Office, Mackenzie

Ross Lennox (Planning Forester – Buffalo Head / Ospika, Slocan) **and Pamela Hengeveld** (Wildlife Ecologist, Wildlife Infometrics Inc) **are jointly presenting a progress report on**

Mountain Goat Habitat Supply Modeling in the Mackenzie TSA:
Developing a Tool for Forest Management and Planning

Objectives of this presentation:

- A brief review of the Ospika Mountain Goat Project
- Introduce the concept of Habitat Supply Modeling for mountain goats
- Provide an overview of the mountain goat habitat models developed during the workshops
- Discuss operational applications of the model and anticipated benefits to industry and government, including:
  - The model's role as a "predictive habitat tool" for identifying mountain goat habitat
  - The model as a mechanism to evaluate habitat impacts of proposed development
- Identify future direction for this project

Background:

Slocan Forest Products – Mackenzie Operations hosted a series of 3 workshops in February and March 2003 to initiate development of a Habitat Supply Model for mountain goats.

The intent of the workshops was to construct a preliminary, Mineral Lick Habitat Supply Model to address concerns of habitat supply and alternative mineral sources for mountain goat populations potentially impacted by forest harvesting. This is the initial step in developing a formal, comprehensive Mountain Goat Habitat Supply Model that can be used by the forest industry at a regional and provincial level to plan the provision of mountain goat habitat in the context of sustainable forest management.

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Slide 1

Mountain Goat Habitat Supply Modeling in the Mackenzie TSA:

Developing an Operational Tool for Sustainable Forest Management

Slide 2

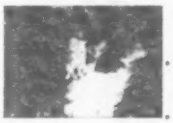
Presented by

Pamela Hengeveld
Wildlife Ecologist (RPBio), Wildlife Infometrics Inc
(*under contract to Slocan*)

Ross Lennox
Planning Forester (RPF), Slocan

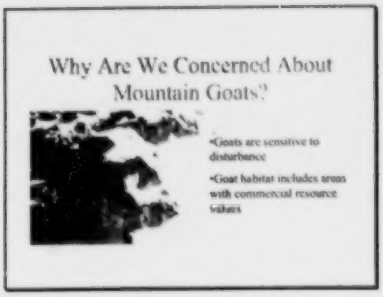
Slide 3

Introduction

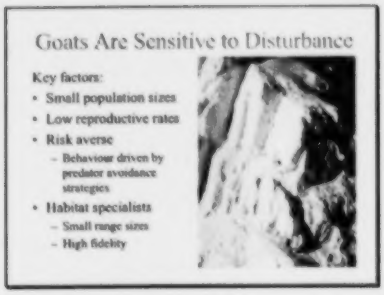


- Mountain goat management concerns in the Mackenzie TSA
- The Ospika Mountain Goat Project
- Habitat Supply Modeling

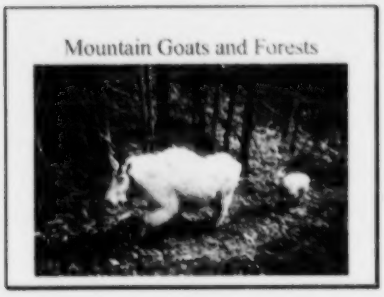
Slide 4


Why Are We Concerned About Mountain Goats?
•Goats are sensitive to disturbance
•Goat habitat includes areas with commercial resource values

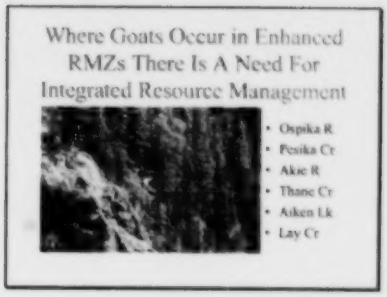
Slide 5



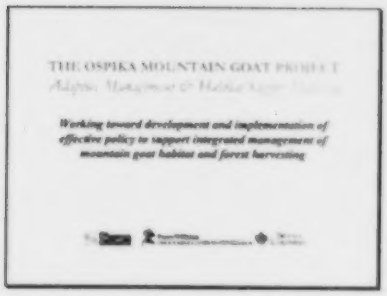
Slide 6



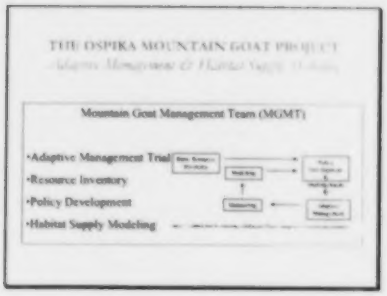
Slide 7


Where Goats Occur in Enhanced RMZs There Is A Need For Integrated Resource Management
• Ospika R
• Pesika Cr
• Akie R
• Thanc Cr
• Aiken Lk
• Lay Cr

Slide 8


THE OSPIKA MOUNTAIN GOAT PROJECT
Working toward development and implementation of effective policy to support integrated management of mountain goat habitat and forest harvesting

Slide 9



Slide 10

Slide 11

Slide 12

Slide 13

Habitat Supply Modeling (HSM)

"Models can be used to organize our thinking, to challenge us to precisely articulate what we profess to know, and to generate new hypotheses to test. " [illegible]

Modeling is a way of constructing a strategic, resource management, decision-making framework that can evaluate a variety of management options.

Slide 14

CHASE

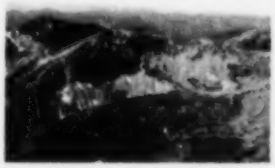
Slide 15

Applying CHASE Principles to Other Species

- Use the experience gained from CHASE model development & application to foster model-motivated management strategies for other species
- Aim to maintain excellent collaboration
- Aim to reduce model development time

Slide 16

Goat Habitat Supply Modeling



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The remainder of this presentation is intended to:

- Provide an overview of the models developed during Jan-Mar 2003
- Discuss operational applications of the model and anticipated benefits to industry and government
- Identify future direction for goat HSM

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Goat HSM Goals

Short-term (to March 31, 2003):

- Build a goat mineral lick HSM
- Run a trial application of the model for the lower Ospika R drainage.

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Goat HSM Goals

Long-term - Produce a tool for:

- Predicting goat habitat potential
  - Enables pro-active planning and management
- Evaluating potential impacts resulting from forestry activities
  - Enables comparisons of alternative forest development plans and management options

Slide 20

Building the Goat HSM

- 3 workshops held in February and March
- Participants included the MGMT and individuals conducting mountain goat research
- Facilitated by Rick Ellis

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Initial Steps

Identify:

- What is known about mountain goats
- Issues of management concern
- Knowledge gaps (assumptions and hypotheses in the absence of 'hard' data)
- Management options

Slide 22

'Scoping' Results

- A list of factors that we think
  - are important in defining (predicting) goat habitat
  - have significant disturbance impacts on goats

Slide 23

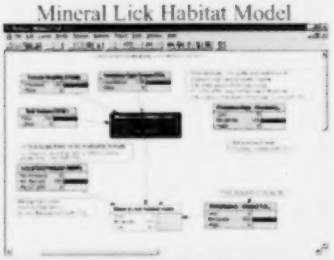
Describing the Relationship Among the Factors

Netica is:

- Computer software
  - designed to illustrate networks of information
- A powerful communication tool
  - factors and their inter-relationships are explicitly defined

Slide 24

Mineral Lick Habitat Model



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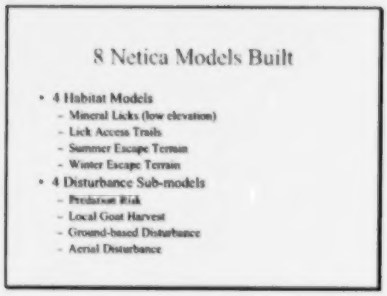
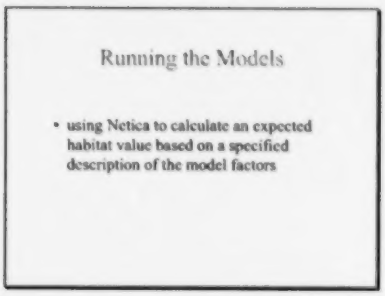
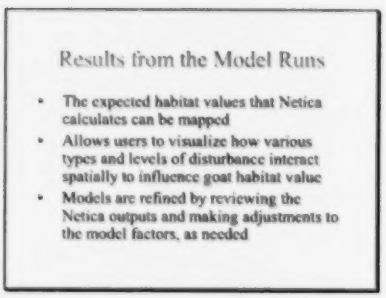


Slide 26


Running the Models
• using Netica to calculate an expected habitat value based on a specified description of the model factors

Slide 27


Results from the Model Runs
• The expected habitat values that Netica calculates can be mapped
• Allows users to visualize how various types and levels of disturbance interact spatially to influence goat habitat value
• Models are refined by reviewing the Netica outputs and making adjustments to the model factors, as needed

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Current Status of the Goat HSM

Short-term goals achieved:

Products include 8 Netica models, documentation, posters showing results of trial application, model user's guide

Now we want to focus on the long-term goal:

Making the models useful as an operational forest planning tool

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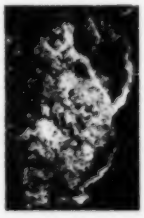
Next Steps

Address the obvious questions!

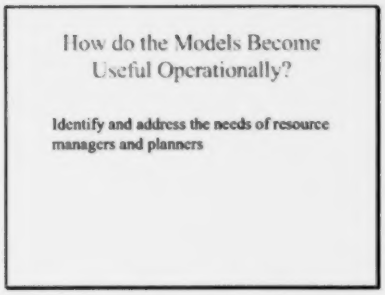
- Do the models accurately predict where goat habitat is?
- Do the models provide an accurate assessment of goat habitat value?
- How do the models become useful as operational planning and management tools?

Slide 30

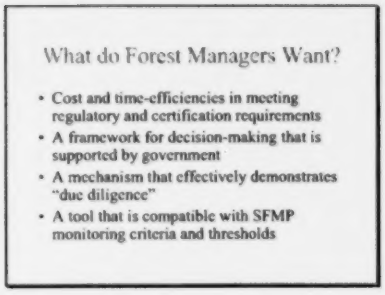
Can the Models Predict Habitat Distribution and Value ?



Slide 31



Slide 32


What do Forest Managers Want?
• Cost and time-efficiencies in meeting regulatory and certification requirements
• A framework for decision-making that is supported by government
• A mechanism that effectively demonstrates "due diligence"
• A tool that is compatible with SFMP monitoring criteria and thresholds

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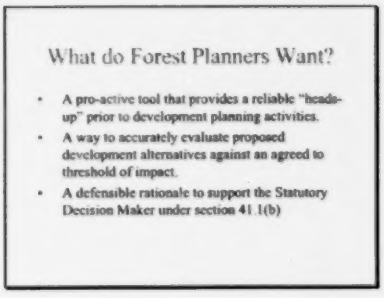
What do Forest Planners Want?
• A pro-active tool that provides a reliable "heads-up" prior to development planning activities.
• A way to accurately evaluate proposed development alternatives against an agreed to threshold of impact.
• A defensible rationale to support the Statutory Decision Maker under section 41.1(b)

Slide 34

What do Forest Planners Want?

- The ability to demonstrate that the intent of the LRMP has been followed
- Timely FDP approvals and the elimination of post-FDP delays
- The ability to demonstrate due diligence

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What do Wildlife / Habitat Managers Want?

- The ability to predict habitat features of management concern (to develop pro-active management plans for important habitat features)
- The ability to identify indicators of and criteria for sustainability, and threshold levels of impact
- The ability to evaluate management options
- A framework for policy development

Slide 36

How Does Our HSM Approach Meet Operational Needs?

- Provides a basis for communication regarding the causal relationships involved in mountain goat ecology
- Considers relevant operational management factors
- Incorporate field data and professional expertise
- Includes a framework for analysis and decision-making
- Provides a transparent structure for the evaluation of results

Slide 37

Summary

- The models are developed collaboratively and designed to meet stakeholder needs
- The models are dynamic, explicit, transparent, and adaptable

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Summary

Operationally, the models provide industry with a mechanism to be:

- Pro-active
- Accountable
- Improve efficiency in decision-making and plan approvals
- Stay flexible

Slide 39

Project Contacts

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